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With the compliments of

John C. Branner,

State Geologist of Arkansas,

Palo Alto, California.

ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

OF

ARKANSAS

FOR 1892

VOLUME I

THE IRON DEPOSITS OF ARKANSAS

By R. A. F. PENROSE, JR., Ph. D.

JOHN C. BRANNER, PH. D.
State Geologist.

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OFFICE OF THE GEOLOGICAL SURVEY OF ARKANSAS,
LITTLE ROCK, ARK., Aug. 1, 1892.

To His Excellency,
Hon. James P. Eagle,
Governor of Arkansas.

Sir:

I have the honor to submit herewith Volume I of my annual report for 1892, and to remain,

Your obedient servant,
JOHN C. BRANNER,
State Geologist.

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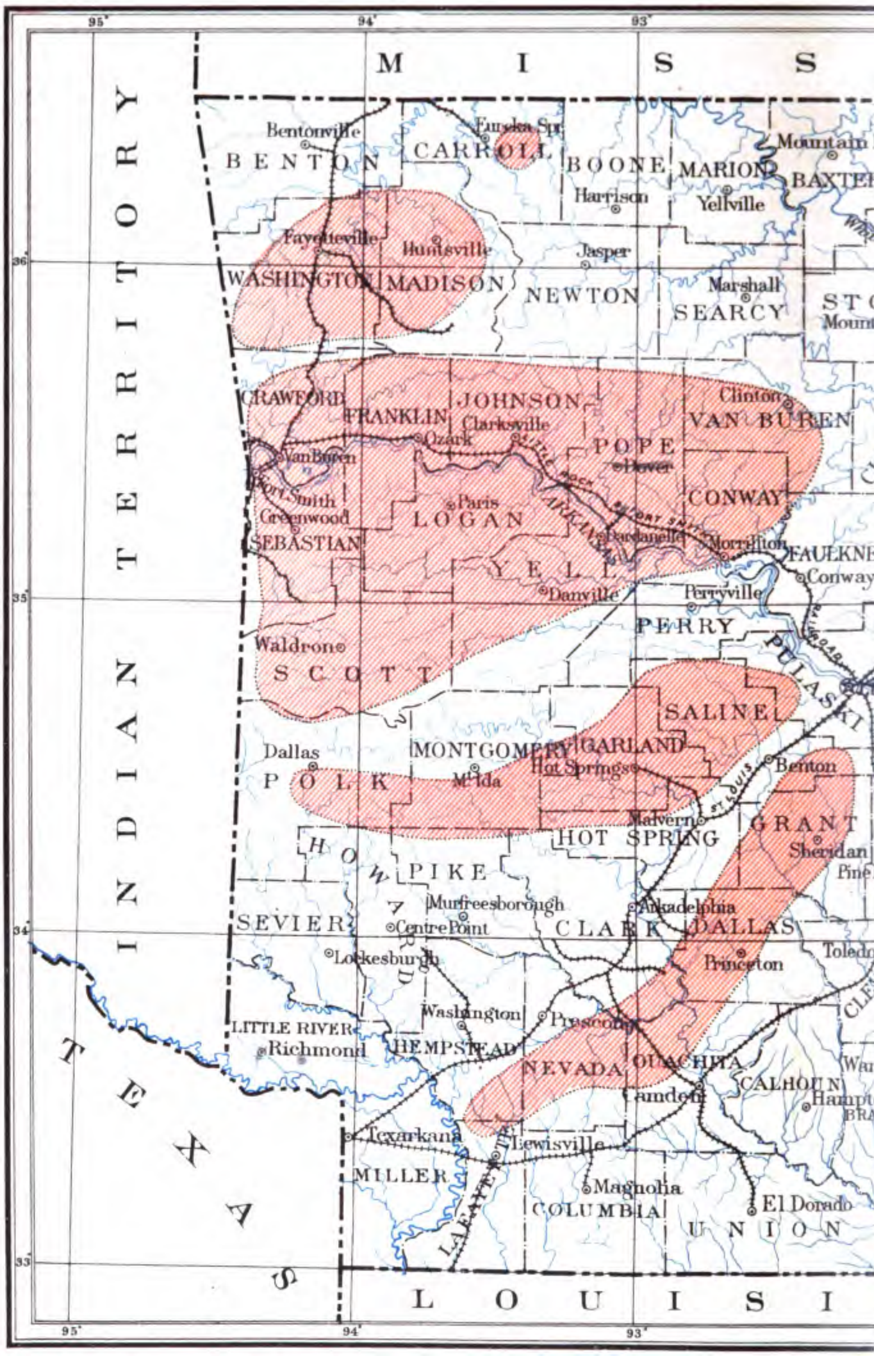
PREFACE.

The results of the Survey's investigation of the iron deposits of the state have not met the expectations and hopes of their commercial value, with which the work was begun. The number of places at which iron deposits occur throughout the state is almost endless, but the examinations of these deposits and the chemical analyses of the ores show that most of them are either too limited in extent, or that they are too low in grade to admit of their being worked. The deposits of Lawrence and Sharp counties are the only ones that merit attention, and whether those deposits can be worked now must depend on economic conditions—transportation, markets and competition.

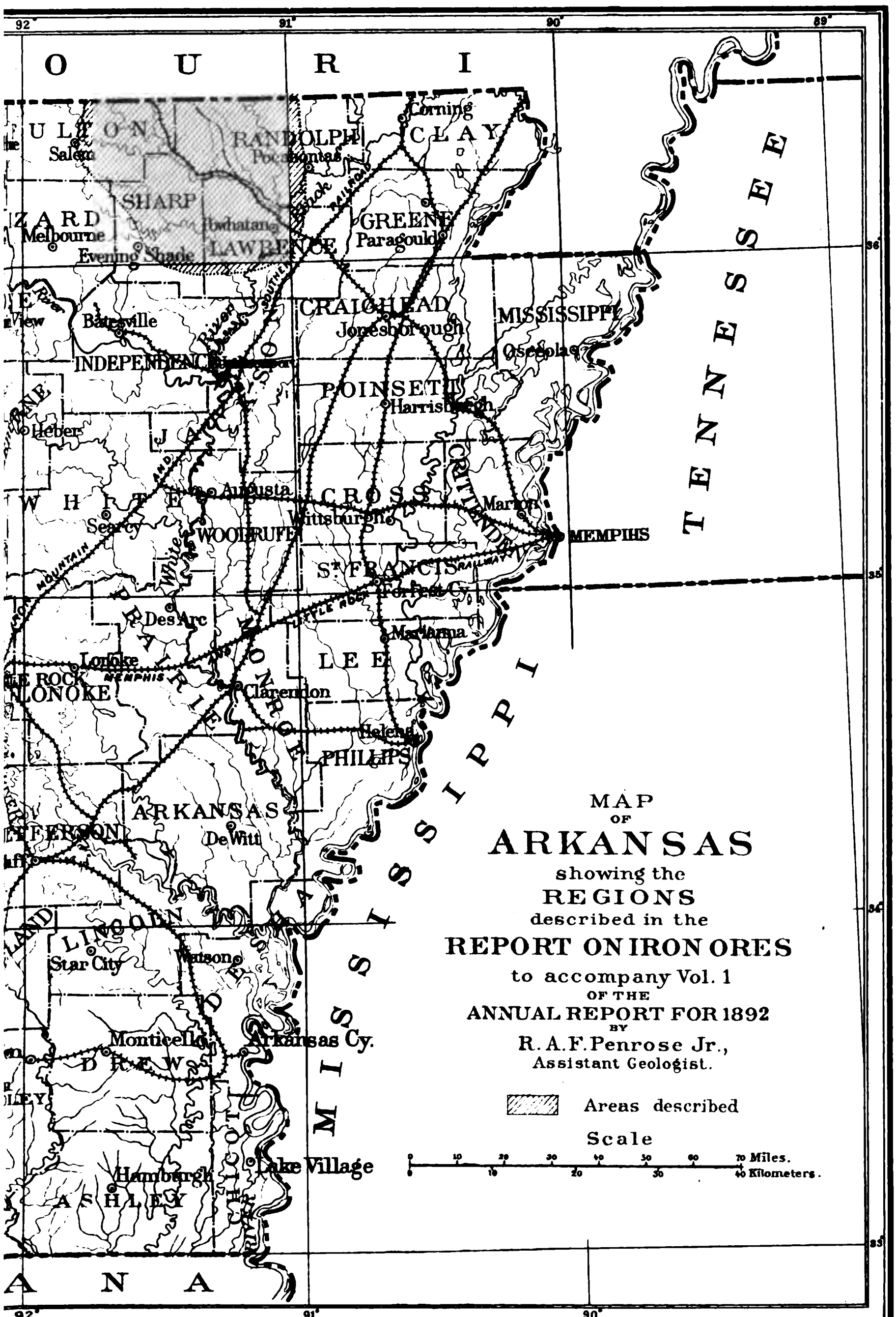
The fact that iron was made in Arkansas prior to 1860 is sometimes mentioned as evidence that we might manufacture it now. It should be remembered, however, that, since that time, the building of railways and the low rates at which good iron can be had from Missouri and elsewhere, have entirely done away with the conditions under which it was possible to make iron in 1860.

JOHN C. BRANNER,
State Geologist.

THE GEOLOGICAL SURVEY OF ARKAN



AS. JOHN C. BRANNER, STATE GEOLOGIST Plate I.



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THE IRON DEPOSITS OF ARKANSAS.

By R. A. F. PENROSE, JR., Assistant Geologist.

CHAPTER I.

THE IRON RESOURCES OF ARKANSAS.

THE HISTORY OF IRON MINING AND MANUFACTURE IN ARKANSAS.

General statement.—The history of iron mining and manufacture in Arkansas is told in a few words. At the present time (1892) no iron ore is being mined and no iron is being manufactured in the state. Two small bloomaries were operated in the northern part of the state for short periods before 1860, and the limited products of those works represent all the iron ever manufactured in Arkansas. Besides the small quantities of ore taken from local deposits to supply these bloomaries, no iron ore has been mined in the state except in prospecting. Prospecting, however, has been done in many places, and the numerous small openings wherever iron ore has been discovered attest to the endeavors that have been made to find it in quantities.

The two bloomaries already referred to were known as the Bevens Bloomary and the Beach Iron Works, and were situated respectively in the northeastern and northwestern parts of the state. They were both operated for only short periods of a few years at the most, and both had already been abandoned in 1860. They were built to supply a purely local demand, and the conditions that permitted their existence were the lack of transportation facilities, there being at that time no railways

in the northern part of the state, and the consequent difficulty of obtaining iron from outside sources. They attained their purpose in this respect, and supplied a serviceable iron for agricultural implements, wagon tires, and other such articles. The abandonment of the bloomaries in both cases is said to have been caused by the limited market for the iron, as there were only sparsely settled country districts to supply. To this cause also may probably be added the inexperience of the operators of the bloomaries.

Though the only two iron-producing works ever erected in Arkansas were thus brought to an early end, yet the improved transportation facilities a few years later and the resulting influx of cheap iron and cheap farming implements would probably have caused their abandmonment even if they had previously been profitably operated. Whatever success they may have attained depended upon their protection against outside iron, and this protection was due to the comparative inaccessibility of the region at that time; but when the protection was removed by the introduction of transportation facilities, their small capacity, crude methods and, in the case of the Beach Iron Works, the scarcity and poor quality of the ore would inevitably have caused their abandonment.

The Bevens Bloomary.—The Bevens Bloomary was situated on Big Creek in the southeastern part of Sharp county, six miles southwest of Smithville, in 16 N., 4 W., the east half of section 24. It was built in 1857 by Alfred Bevens & Co., and was run for two or three years, when operations were stopped on account of the limited market for the iron produced. At the present time most of the bloomary has been swept away or covered with sand by the overflows of Big Creek. The ores for the bloomary were obtained from the local deposits in the neighborhood, in Sharp and Lawrence counties.

Dr. D. D. Owen,* in referring to the Bevens Bloomary after his visit there in 1857–58, says "it has two fires, and is driven by a good water power. When visited, this forge was under-

*First Report of a Geological Reconnoissance of the Northern Counties of Arkansas 1857-1858, p. 218.

going thorough repairs, and preparations were being made to introduce the hot blast in place of the cold blast, formerly in use, by which alteration it was expected to increase the amount of swaged bar iron manufactured from (500) five hundred to (1600) sixteen hundred pounds per day." Prof. J. P. Lesley,* however, in speaking of the Bevens Bloomary somewhat later (1859) says, "It was built in 1857 with two fires and one hammer driven by water, and makes 250 pounds of swedged iron per day with cold blast, out of brown hematite ore."

The Beach Iron Works.—The Beach Iron Works consisted of a bloomary and were situated in the central part of Carroll county, on the east side of Osage Creek, less than a mile above its confluence with King's River. It is said to have been erected in 1850 or soon thereafter, and to have been abandoned before 1860, in which year it was destroyed by a freshet. Full records concerning it are at present unobtainable. It was built by an Englishman named Abram Beach,† and it is said by some to have been worked for several years, by others, for only a few months. At any rate, it was run on only a small scale and for a short time. Like the Bevens Bloomary, it was built to supply a local demand and, as in the case of the latter, the cause that permitted its existence and operation was the difficulty of obtaining iron from outside sources. The ore for the Beach Bloomary was obtained from the local deposits of Carroll county, in the vicinity of Berryville, which are described later in this report.

PREVIOUS GEOLOGIC INVESTIGATIONS OF THE IRON DEPOSITS OF ARKANSAS.

Before the present investigation was begun no comprehensive examination of the iron deposits of Arkansas had been made. Dr. D. D. Owen‡ and his assistant, Edward T. Cox,

*The Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States, J. P. Lesley, 1859, pp. 216–217.

†History of the Manufacture of Iron in all Ages, by James M. Swank, second edition, 1892, p. 342.

‡First Report of a Geological Reconnoissance of the Northern Counties of Arkansas, 1857–1858; also Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas, 1859–1860.

in their reports on the various counties of Arkansas mention the existence of iron ores in many places, but no detailed investigation of them was made, and they are referred to only incidentally and in the general descriptions of different regions.

The magnetic ore of Magnet Cove, on account of its remarkable qualities as a loadstone, has attracted more attention than any other iron deposit in the state; and it is mentioned by United States Geologist Featherstonhaugh* and by many other investigators and travelers both before and after the time of Owen. Most of the early writers, however, including both Featherstonhaugh† and Owen‡ were deceived as to the quantity of the ore, and believed it to be a large deposit. In 1859 Professor J. P. Lesley|| mentioned the manufacture of iron at the Bevens Bloomary, but did not describe the ore deposits in that region.

In 1884§ and again in 1892¶ Mr. James M. Swank described the manufacture of iron at the Bevens Bloomary and the Beach Iron Works in northern Arkansas.

The reports of the present Geological Survey of Arkansas since 1887 contain numerous references to iron ore localities and occasionally a few descriptions of deposits, but the examinations were usually made incidentally and were subordinate to other investigations. Dr. T. B. Comstock** describes several iron ore localities in Pulaski, Saline and other counties farther west in the Ouachita Mountains. Prof. R. E. Call†† mentions several iron ore localities in eastern Arkansas and concludes that they are of no commercial value. Dr. J. Francis Williams‡‡ gives a full description of the magnetic ore

*Geological Report of an Examination made in 1834 of the Elevated Country between the Missouri and Red Rivers, by G. W. Featherstonhaugh, Washington, 1835.

†Ibid., p. 68.

‡Second Report of Geological Reconnoissance of the Northern Counties of Arkansas, 1859–1860, p 31.

||The Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States, 1859, pp 216–217.

§History of the Manufacture of Iron in All Ages, 1884.

¶Ibid., 1892, pp. 341–342.

**Annual Report of the Geological Survey of Arkansas, 1888, Vol. I.

††Ibid., 1889, Vol. II.

‡‡Ibid., 1890, Vol. II.

of Magnet Cove, and shows that it is in too small quantities to be worked as a source of iron. Many other references to Arkansas iron ores in the reports of the present Survey might be cited, but it is unnecessary to do so, as, with the exception of those of Dr. Comstock and Dr. Williams, they are simply brief notices of the existence of iron deposits, all of which are further treated in the present report.

Besides the information contained in the reports of the Survey, numerous references to iron ore deposits are to be found in various state documents, in reports on the resources of the state, and in periodicals and in newspaper accounts; but they are all brief, and in many cases the authors were obliged to rely upon hearsay evidence for their information regarding the deposits.

In 1886 Prof. F. L. Harvey, then of the Arkansas Industrial University at Fayetteville, published a pamphlet* in which he describes the different kinds of iron ore in the state.

The annual reports on the Mineral Resources of the United States, under the direction of Dr. David T. Day, from 1885 to the present time contain many notices of the existence of iron ores and manganiferous iron ores in Arkansas. In the report for 1885 a notice of manganiferous iron ore in the Batesville region was made in the article on iron by Mr. James M. Swank (p. 188). In 1887 the pisolitic iron ores of southern Arkansas were mentioned in the article on iron by Mr. John Birkinbine (p. 49).

The issue of the *Age of Steel*, of St. Louis, Missouri, for September, 3, 1887, contains an article on the manganese and iron deposits of Polk county, together with analyses and a general description of the region.

With the exception of the above mentioned publications, however, and occasional reports for mining companies, no further information of importance on the iron deposits of Arkansas has as yet appeared.

*The Minerals and Rocks of Arkansas, Little Rock, 1886.

THE DISTRIBUTION OF IRON ORE IN ARKANSAS.

Iron ore is of common occurrence throughout many parts of Arkansas, but in only a few places is it found in important quantities. The largest and most accessible deposits yet discovered are in the northeastern part of the state, especially in Lawrence and Sharp, and to a lesser extent in Fulton and Randolph counties. Other deposits, however, of varying size and importance occur in many places in the part of the state west and north of the line of the St. Louis and Southwestern Railway ("Cotton Belt Route").

In the descriptions of the various iron ore localities of Arkansas, given later in this report, the state will be divided, for the sake of convenience, into five different parts, and each will be treated separately, as follows:

(1.) *The iron deposits of Northeastern Arkansas.*—(Lawrence, Sharp, Fulton and Randolph counties.)

(2.) *The iron deposits of Northwestern Arkansas.*—(Carroll, Washington and Madison counties.)

(3.) *The iron deposits of the Arkansas Valley.*—(Van Buren, Conway, Pope, Yell, Johnson, Logan, Franklin, Sebastian, Scott and Crawford counties.)

(4.) *The iron deposits of the Ouachita Mountains.*—(Pulaski, the northern part of Saline, Hot Spring, Clark, Pike, Montgomery and Polk counties.)

(5.) *The iron deposits of Southern Arkansas.*—(The southern part of Saline county, Dallas, Ouachita, Nevada, Hempstead and Lafayette counties.)

The above five divisions include a large part of the state, but in only a few places in these regions has ore of importance been discovered. A common though natural error made by many people is to mistake a brown ferruginous sandstone, which is characteristic of many of the Carboniferous and Lower Carboniferous formations in the state, for iron ore. This rock contains from 40 to over 60 per cent of silica and from 15 to 30 per cent of iron, and is therefore worthless as a source of iron. Under delusion as to its value, however, many

people have thought that they possessed immense iron ore deposits, which on examination by the Survey gave the result above stated. The ores from many of these localities are further described later in this report for the benefit of those interested in them, and several analyses are given.

THE GEOLOGIC RELATIONS OF THE IRON DEPOSITS OF ARKANSAS.

The geologic distribution of iron ore in Arkansas is as general as its geographic distribution just described. It occurs in almost every series of rocks represented in the state, from Lower Silurian to Recent, except in the Cretaceous. Taking up the five iron ore regions in the order of the classification on page 6, it will be seen that the different geographic divisions given there conform in a general way to the geologic divisions: The ores of northeastern Arkansas are associated with Lower Silurian (probably Calciferous) sandstones, cherts and limestones; the ores of northwestern Arkansas, in the central part of Carroll county, occur mostly with Lower Silurian cherts, while those of Washington and Madison counties are mostly in Lower Carboniferous sandstones; the ores of the Arkansas Valley occur almost exclusively with rocks of Carboniferous and Lower Carboniferous ages, though some of them are much later deposits formed by the concentration, at the mouths of springs, of the iron in rocks of those ages; the ores of the Ouachita Mountains cccur mostly with Lower Silurian shales and novaculites, though they also include the magnetic ore of Magnet Cove, which occurs in an area of igneous rock in the novaculite region; the ores of the southern part of the state are in a great series of sands and clays which represents the Eocene division of the Tertiary.

This very general distribution of iron in rocks of different ages is, however, not peculiar to Arkansas. Iron is one of the most universally and most abundantly distributed of all known metals in the rocks of all ages and in all regions, though elsewhere, as in Arkansas, it has accumulated in commercially important quantities only in local areas.

THE CHARACTER AND COMMERCIAL VALUE OF THE IRON ORES OF ARKANSAS.

Varieties of ores.—Most all the iron ores of Arkansas belong to the class of hydrous sesquioxides of iron, or limonite,* commercially called brown hematite, or simply "brown ore." The only other ores found in the state are limited quantities of carbonate of iron or spathic ore, also known as clay-ironstone, found in the Carboniferous shales and in the Tertiary clays and sands, and still more limited quantities of magnetic ore (magnetite) occurring in a residual clay derived from the decay of a crystalline rock in Magnet Cove. This last ore is the celebrated Arkansas loadstone.

On account of the very limited quantities of the carbonate and the magnetic ores, it is only necessary to discuss here the market value of the brown hematites, while the others will be further mentioned in the descriptions of individual localities.

Commercial value.—The first question which comes up in considering the commercial value of an ore is whether or not it is fit to make Bessemer steel; and so important has this point become that all iron ores may be classified, from a commercial standpoint, as either "Bessemer" or "non-Bessemer." The term Bessemer steel is used because the vast bulk of the steel now manufactured in this country is made by the Bessemer process. The main requisite of an ore fit to make Bessemer steel is that it should contain a minimum amount of phosphorus, though there must be of course a sufficiently large percentage of iron to make the ore available, and the percentages of sulphur, silica and other impurities must also be sufficiently small, as further explained below. Most of the iron ores of the world are non-Bessemer and are sold at a cheaper rate than the Bessemer ores. A Bessemer ore should not contain over 0.05 per cent of phosphorus, and if it contains much more than this amount it is deemed unfit for the manufacture of Bessemer steel and can be used only for making the com-

*According to J. D. Dana, limonite means a hydrous sesquioxide of iron, containing a certain percentage (14.4 per cent) of water as indicated by the formula $2Fe_2O_3 . 3H_2O$, but the term is also often used to mean any hydrous sesquioxide of iron. For the sake of convenience in description this general application will be used throughout this report.

moner grades of iron*. Of course in determining the amount of phosphorus allowable in a Bessemer ore, the percentage of iron present must be considered, since an ore high in iron may contain a larger percentage of phosphorus than an ore low in iron and yet the ratio of the iron to the phosphorus may remain the same. For this reason the amount of phosphorus allowable in a Bessemer ore varies within certain narrow limits and in direct ratio with the percentage of iron. Steel can be made and is made by what is called the basic process, but the commercial success of this method on a large scale in this country has yet to be demonstrated, and many of the best authorities on iron doubt its possibilities of success under the conditions existing in the United States, especially in view of the immense quantities of low-phosphorus ores suitable for the Bessemer process now mined in the Lake Superior region and elsewhere in this country.

It will be observed from the accompanying table of analyses that the percentage of phosphorus in the Arkansas ores varies considerably, from less than 0.01 per cent to over 1 per cent. Most of the analyses show the ores to be non-Bessemer, and in most of the cases where the phosphorus is low enough to permit the ore to pass as Bessemer, the quality is injured by the high percentage of silica or else the ore occurs in quantities too small to be of commercial value. In a few cases, however, the analyses of samples from deposits of ore of considerable size show them to be Bessemer as regards phosphorus, to be fairly good in iron and low in silica. Such ores could be used in making Bessemer steel if the average production of the mines ran as well as the samples of which analyses are given. This could only be determined by thoroughly stripping, prospecting and sampling the deposits in many places, a task which the time and means of the Survey have not permitted it to undertake. In the cases, therefore, where the accompanying analyses indicate a Bessemer ore,

*Sometimes an ore containing slightly over 0.05 per cent of phosphorus is used for what is technically called "Bessemer mixture," that is, it is utilized by mixing it with an ore containing an exceptionally small percentage of phosphorus, the final mixture being not over 0.05 in that ingredient.

they are not to be considered as conclusive as to the good quality of the whole deposit, but simply indicative of such a possibility. Such analyses will be further discussed under the treatment of individual localities.

Though, as will be seen by the analyses, most all the Arkansas iron ores are too high in phosphorus to be used for Bessemer steel, they have this property in common with almost all the iron ores of the south Atlantic states. The iron ores of Virginia, Tennessee, Georgia and Alabama are practically all non-Bessemer, no Bessemer ore being obtained from the celebrated Birmingham deposits. Though the field of Bessemer steel is thus shut off from most, if not all of the Arkansas ores, many of them would be suitable, where found in sufficient quantities, for the manufacture of pig-iron for foundry purposes and for the numerous applications of iron to industrial uses.

In their contents of iron the Arkansas ores range from 35 to over 55 per cent, rarely, however, reaching the latter figures when sampled in large quantities. In many cases individual specimens could be selected which would show by analysis as much as 60 per cent or more of iron, but no such average could be obtained in large shipments of the ores. In many of the analyses it will be observed that the average of iron is much lower than 35 per cent, and in several cases it falls even below 10 per cent. Such analyses were made of materials which are commonly mistaken for iron ore throughout the state, but which are really brown or red sandstones or shales colored by iron. Such a mistake is very common and has caused many people in the state to believe that they have large deposits of iron ore when they have simply a rusty rock of no commercial value whatever as an ore. The analyses are given for the benefit of those who may think these materials valuable, as their nature was evident to the Survey before the analyses were made.

In their contents of silica the Arkansas ores have as wide a range as in their contents of iron. The analyses show the silica to vary from 2 per cent to over 75 per cent. When the

Analyses of Arkansas iron ores.

Number.	LOCALITY.	Iron.	Silica	Phosphorus.	Sulphur.	Manganese.	Analyzed by
	NORTHEASTERN ARKANSAS.						
	LAWRENCE COUNTY.						
1	Coffman tract, 17 N., 1 W., Sec. 17, S. ½ S. E.	55.75	5.20	0.041	0.212	A little	A. E. Menke.
2	Holloway tract No. 1, 16 N., 2 W., Sec. 6, S. E.	53 91	7.08	0 028	0.198	" "	" "
3	" " No. 2, 17 N., 3 W., Sec. 35, N. E., S. E.	45.49	8.47	0 007	0.815	" "	" "
4	Cazort tract, 16 N., 2 W., Sec. 6, N. W., S. W	41.71	28.26	0.014	0.232	" "	" "
5	Holloway & Collins tr'ct No. 1, 16 N., 3W., Sec. 12, S. E.	49.44	25.85	0.028	0.479	" "	" "
6	" " " No. 2, 16 N., 3W., Sec. 12, W. ½, W. ½	47.99	15.08	0.088	0.054	" "	" "
7	Wasson tract No. 1, 17 N., 3 W., Sec. 26, S. ½	41.58	16.26	0.198	0.095	" "	" "
8	Sloan tract, 17 N.. 3 W, Sec. 28, W. ½, N. E	40.10	12.54	0.042	0.637	" "	" "
9	Strawberry or Cathaytown, 16 N., 3 W., Sec. 12, S. E.	36.30	30.87	0.041	0.205	None.	" "
10	" " " " " " " " "	27 35	52.58	0.284	0 084	" "	" "
	SHARP COUNTY.						
11	Collins tract, 16 N., 4 W., Sec. 8, S. W	58.91	2.46	0.088	0.109	Trace.	" "
12	Wasson tract No. 2, 16 N., 4 W., Sec. 18, E. ½ S. E	54.70	2.80	0.021	0.458	None.	" "
13	Big Creek & Reed's Creek divide. 16 N., 4 W., Sec. 36, N. ½	23.67	58.12	0.306	0.178	" "	" "
	FULTON COUNTY.						
14	Deadrick tract, 20 N., 6 W., Sec. 1	44.97	21.40	0.031	0.109	" "	" "
	RANDOLPH COUNTY.						
15	Near Ravenden Springs	50.49	12.60	0.041	0.102	A little	" "
16	Odom tract, 18 N., 1 W., Sec. 18, N. E., N. E	44.44	11.88	0.021	0.157	" "	" "
17	Iron Bank, 21 N., 3 W., Sec. 8, N. E., S. W	49.97	14.58	0.014	0.082	Trace.	" "
	NORTHWESTERN ARKANSAS.						
	CARROLL COUNTY.						
18	Bobo tract, near Berryville	47.33	5.36	0.028	0.287	A little	" "
19	Mack Thomas tract, near Berryville	45.01	6.82	0.085	0.301	" "	" "
20	Brooks tract, near Berryville	21.96	50 42	0.299	4.486	None.	" "
	WASHINGTON COUNTY.						
21	Near Tolu, 14 N., 33 W., Sec. 16, N. W.	18.62	60.80	0.046	.....	4.08	R. N. Brackett.
	ARKANSAS VALLEY.						
	VAN BUREN COUNTY.						
22	McGruder tract, near Choctaw	24.40	40.44	0.276	0.178	A little	A. E. Menke.

Analyses of Arkansas iron ores.—Continued.

Number.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyzed by
23	Lick Mountain, near Choctaw	20.98	18.78	0.524	0.123	A little	A. E. Menke.
	POPE COUNTY.						
24	Guest tract, near Russellville ....:	24.40	46.36	0.242	0.164	Trace.	" "
25	Bowden tract, 8 N., 19 W., Sec. 17, N. E., N. E......	33.55	18.42	0.262	0 054	None.	" "
26	Barton tract, 8 N., 19 W..............................	17 56	63.64	0.312	0.178	Trace.	" "
	LOGAN COUNTY.						
27	Freeman's Gap, near Paris.	19.76	36.32	0.241	0.137	None.	" "
	SEBASTIAN COUNTY.						
28	Wild Cat Mountain, near Fort Smith.................	17.81	10.84	0.414	0.411	A little	" "
	SCOTT COUNTY.						
29	"Near Mansfield," 4 N., 30 W., Sec. 6...............	14.15	51.50	0.286	0.049	None.	" "
	CRAWFORD COUNTY.						
30	Shay tract, near Lancaster..	17.08	40 30	0.274	0.260	A little	" "
31	Near Chester	15.37	42.54	0.184	0.054	" "	" "
32	Basham tract, near Chester..........................	28.30	37.22	0 252	0 128	" "	" "
	OUACHITA MOUNTAINS.						
	PULASKI COUNTY.						
33	Capitol L. & M. Co tract, 1 N., 14 W., Sec. 24, N. E.	33.80	44.91	0.160	....	0.39	R. N. Brackett.
34	" " " " " " " Sec. 24, S. E., N.W	11.82	63.19	0.270	....	8.08	" "
35	Whittemore & Bunch tract, 1 N., 14 W., Sec. 14 N. E., S. W........	27.07	46.37	0.470	....	1.62	" "
36	R. W. Worthen tract, 1 N., 13 W., Sec. 19, S. W., S. W.	6.10	75.02	0.184	0.137	None.	A. E. Menke.
37	" " " 1 N., 14 W., Sec. 14, N. E., S. W.	53.42	22.48	0.500	.....	Trace.	R. N. Brackett.
	SALINE COUNTY (Northern part).						
38	Iron Mountain, 2 N., 16 W., Sec. 18, S. E	35.74	42.79	0.140	.....	A little	" "
39	" " " " " " " "	11.34	50.60	0.276	0.082	None	A. E. Menke.
	GARLAND COUNTY.						
40	Rector & Roulston claim No. 1, 4 S., 19 W., Sec. 3, S.E	57.54	2.96	0.670	.....	None.	W. A. Noyes.
	HOT SPRING COUNTY.						
41	Conley Sullivan claim, 4 S., 20 W., Sec. 26, N. W. S. E.	14.15	1.29	0.560	.....	41 54	" "
42	Magnet Cove, 3 S., 17 W., Sec. 20, S. W....	68.58	5 86	0.028	0.191	A little	A. E. Menke.
	MONTGOMERY COUNTY.						
43	Bud Jones claim No 1, 3 S., 23 W., Sec. 22, S. E., N. E.	61.99	1.53	0.200	.....	0 04	W. A. Noyes.
44	" " " No. 3, 3 S., 23 W., Sec. 29, N. ½.....	54.54	0.84	1.790	.....	0.30	" "

Analyses of Arkansas iron ores.—Concluded.

Number.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyzed by
	POLK COUNTY.						
45	J. Guy Lewis claim, 4 S., 28 W	16.22	19.82	0.778	0.187	Trace.	A. E. Menke.
46	Pointed Rock tunnel, 4 S., 28 W., Sec. 19	14.51	41.40	0.191	0.082	A little	" "
47	Arkansas Development Co. claims..................	25.58	0.80	0.767	.....	40.51	St. L. S. & T. Works.
48	" " " "	35.39	1.88	0.230	.....	27.68	" "
49	" " " "	16.83	29.00	0.343	.....	26 20	" "
50	" " " "	22.26	44.40	0.576	.....	11.93	" "
51	" " " "	50.38	.....	1.450	.....	2.06	" "
	SOUTHERN ARKANSAS.						
	SALINE COUNTY (Southern part)						
52	R. W. Worthen tract, 3 S., 13 W., Sec. 6............	40 94	30 26	0.070	.....	Trace.	R. N. Brackett.
53	" " " " " " " "	22.57	2.96	0.193	0 548	A little	A. E. Menke.
54	Young tract, 2 S, 14 W, Sec. 33, N. E..............	21.10	28.86	0.110	0.178	" "	" "
55	Frank Davis tract, 2 S., 14 W., Sec. 1............	20.98	2.12	0.262	0.452	Trace.	" "
56	Claiborne tract, 2 S., 14 W., Sec. 10................	14.34	3.46	0.124	0.274	A little	" "
57	Wm. Herr tract, 2 S., 14 W., Sec. 3, E. ½ S. W.......	21.96	6 68	0.317	0 041	" "	" "
	DALLAS COUNTY.						
58	Griswold's mill, 10 S., 16 W., Sec. 4................	30.67	40.48	0.704	.....	None.	R. N. Brackett.
59	" " " " " "	37.73	25.87	0.225	....	Trace.	" "
	OUACHITA COUNTY.						
60	Five miles west of Camden, 12 S., 18 W.............	26.15	52.16	0.588	.....	None.	" "
61	Wm. Brown tract, 12 S., 18 W.......................	35.68	35.95	0.280	.....	" "	" "
	NEVADA COUNTY.						
62	Vicinity of Rosston, 13 S., 21 W........................	57.17	4.27	0.225	.....	Trace.	" "
63	" " " " "	50 20	10.65	0.424	....	" "	" "
64	" " " " "	38.80	26.57	0.119	.....	None.	" "
65	" " " " "	30.88	50.63	0.223	.....	" "	" "
66	" " " " "	22.08	58.78	0.085	....	" "	" "
	HEMPSTEAD COUNTY.						
67	Eight miles north of New Lewisville	26.47	52.10	0.201	.....	" "	" "
86	" " " " " "	27.31	53.32	0.136	.....	" "	" "
	LAFAYETTE COUNTY.						
69	Boyd farm, near New Lewisville	38.13	26.78	0 189	. ..	" "	" "
70	" " " " "	19.68	65.82	0.137	.	" "	" "

The analyses in this table, as well as elsewhere in this report, were all made by the Chemists of the Survey, with the exception of Nos. 47-51 inclusive, which were made at the St. Louis Sampling and Testing Works, Prof. W. B. Potter, Manager, and which have been kindly furnished the Survey by Mr. W. E. Barns, editor of the *Age of Steel*, St. Louis, Mo.

silica in an ore amounts to more than about 15* per cent it seriously injures its market value; and it will, therefore, be observed from the analyses that many of the Arkansas ores are high in silica and some of them are excessively so. This high percentage of silica renders many of the ores shown in the table of analyses worthless as sources of iron.

In their contents of sulphur the Arkansas ores range from less than 0.04 per cent to over 1 per cent, but they are generally below 0.5 per cent, and this average compares favorably with that of many other ores which are mined and find a good market. The presence of a limited amount of sulphur is a much less serious objection than the presence of phosphorus.

As will be seen by the analyses, most of the Arkansas ores contain at least a trace of manganese and sometimes enough to allow them to be classified as manganiferous iron ores. The manganiferous iron ores are especially characteristic of the novaculite regions of the Ouachita Mountains.

None of the Arkansas ores, with the exception of the magnetite of Magnet Cove, have been found to contain appreciable quantities of titanium.

Summary.—To summarize the above facts regarding the commercial value of the iron ores of Arkansas it may be said that they are usually, if not always, non-Bessemer in quality, generally containing over 0.05 per cent of phosphorus; in iron they vary from less than 35 per cent to over 55 per cent; in silica they vary from rarely as low as 2 per cent to over 75 per cent, and are often much injured by an excess of this ingredient; in sulphur they range from 0.04 per cent to rarely over 1 per cent; in some localities they contain enough manganese to be classed as manganiferous iron ores; they rarely contain titanium in appreciable quantities.

The following table, comprising a number of analyses of iron ores from well known mines in the United States and Cuba, is given for comparison with the analyses of Arkansas ores in the

*The percentage of silica that an ore can contain and yet command a good price depends partly on the percentage of iron present, for an ore high in iron can safely contain more silica than one low in iron.

Analyses of iron ores of various mines in the United States and Cuba.

No.	LOCALITY.	Kind of ore.	Iron.	Silica.	Phos-pho's.	Sul-phur.	Analyzed by
1	Tilly Foster mine, Putnam Co., N. Y.....	Magnetite..........	48.91	12.18	0.015	0.548	Whitfield.
2	Crown Point, Essex Co., N. Y............	"	63.80	....	0.030	......	Richmond.
3	" " "	"	52.25	.....	0.107	....	"
4	Moriah (Port Henry) "	"	62.64	....	0.908	......	"
5	Chateaugay mine, Clinton Co., N. Y.....	"	66.00	.....	0.008	......	"
6	" " " "	"	52.47	18.44	0.029	0.05	....
7	Andover mine, Sussex Co., N. J..........	"	36.91	21.86	0.022	2.527	Blair.
8	" " " "	"	62.81	.....	0.001	0.059	"
9	Hackelbarney mine, Morris Co., N. J....	"	48.88	.....	0.057	0.529	Chauvenet.
10	Cornwall mine, Lebanon Co., Pa........	"	64.90	3.98	0.014	0.071	McCreath.
11	" " " "	"	57.05	3.65	0.007	2.531	"
12	" " " "	"	51.45	12.27	0.010	2.459	"
13	French Creek, Chester Co., Pa	"	56.13	.....	0.040	......	Whitfield.
14	Hecla Furnace, Lawrence Co., Ohio.....	Siderite	33.29	.....	0.144	......	King.
15	Monroe Furnace, Jackson Co., Ohio	Limonite...........	49.82	.....	0.145	......	"
16	Dover & Co., Amherst Co., Va...........	Specular & magnetite	48.47	21.58	0.108	0.352	Gooch.
17	Panic Furnace, Smyth Co., Va	Limonite...........	46.61	11.47	0.125	0.056	"
18	Cranberry, Mitchell Co., N. C.	Magnetite..........	32.37	29.99	0.010	0.128	Pitman.
19	" " "	"	44.08	.....	0.007	0.128	"
20	Pennsylvania Furnace, Greenup Co., Ky.	Limonite...........	54.89	.....	0.167	......	King.
21	Shepherd Bank, Lawrence Co., Ky	Carbonate	40.61	14.87	0.126	0.227	"
22	Taylor Bank, Carter Co., Tenn..........	Limonite...........	49.78	18.68	0.056	0.066	"
23	Eureka mine, Jefferson Co., Ala..........	Fossil ore	51.25	16.59	0.219	0.139	White.
24	" " Tuscaloosa Co., Ala	Limonite...........	46.59	15.07	0.179	0.318	"
25	Shelby mine, Shelby Co., Ala............	"	52.82	6.62	0.241	0.139	"
26	Pilot Knob, Iron Co., Mo................	Specular ore........	59.52	12.17	0.005	0.020	"
27	Iron Mountain, Saint Francois Co., Mo..	"	64.67	.....	0.019	......	King
28	" " " " " "	"	59.06	.....	0.398	......	"
29	Republic mine, Marquette Co., Mich....	"	67.02	3.38	0.024	0.037	Gooch.
30	Norway mine, Menominee Co., "	"	60.20	12.43	0.047	0.043	Pitman.
31	Commonwealth mine, Marinette Co., Wis.	"	59.36	7.81	0.224	.....	Gooch.
32	Black River Falls, Jackson Co., Wis.....	"	37.09	.....	0.047	......	King.
33	Iron Mountain, Dodge Co., Wis	Fossil ore..........	56.52	.....	0.534	......	"
34	Nipigon, Minn............................	Red specular ore ...	63.88	12.97	0.051	Trace	....
35	Vermilion Range, Minn	" "	67.17	4.61	0.083	0.02	....
36	Marion Co., Texas	Limonite...........	47.55	8.92	0.139	0.07	Herndon.
37	Cherokee Co., Texas....................	"	42.25	25.13	0.118	......	Magnenat.
38	Llano Co., Texas	Magnetite..........	63.74	10.08	0.018	......	....
39	Breece mine, Lake Co., Colo	Specular hematite..	61.51	.....	0.038	......	King.
40	Juragua, Cuba...........................	Magnetite..........	61.94	7.18	0.027	0.332	Beth. Iron Co
41	" "	"	62.54	.....	0.028	0.353	Booth, Garrett & Blair
42	Sigua, "	"	58.10	15.50	0.034	0.046	Rattle & Nye

preceding table. It will be observed that several of the analyses show the ores to be of no better quality than some of the Arkansas ores; but many of the ores represented in the table are only used where they are in close proximity to a cheap supply of good fuel and limestone, and where the transportation facilities and the markets are especially favorable.

Analyses Nos. 1–5, 7–9, 13–33, and 39 are quoted from the Tenth Census of the United States, Vol. 15, on Mining Industries.

Analyses Nos. 10, 11 and 12 are from the Second Geological Survey of Pennsylvania, Annual Report, 1885, Report on the Cornwall Iron Ore Mines, Lebanon county, p. 532, by J. P. Lesley and E. V. d'Invilliers.

Analysis No. 6 is quoted from Bull. N. Y. State Museum Nat. Hist. No. 7, 1889, First Report on the Iron Mines and Iron Ore Districts in the State of New York, p. 42, by John C. Smock.

Analyses Nos. 34 and 35 are quoted from the Geol. and Nat. Hist. Survey of Minnesota, Bull. No. 6, 1891, The Iron Ores of Minnesota, p. 89, by N. H. and H. V. Winchell.

Analyses Nos. 36 and 37 are quoted from the First Annual Report, Geol. Survey of Texas, E. T. Dumble, State Geologist, Preliminary Report, Gulf Tertiary of Texas from Red River to Rio Grande, p. 84, by R. A. F. Penrose, Jr.

Analysis No. 38 was made for the Wakefield Coal and Iron Co.

Analyses Nos. 40 and 41 have been kindly furnished the Survey by Mr. Josiah Monroe, Secretary and Treasurer of the Juragua Iron Co.

Analysis No. 42 is quoted from the report on the Sigua Bessemer Iron Ore Mines in Cuba, by W. J. Rattle, 1890, p. 36.

THE IRON MINING POSSIBILITIES OF ARKANSAS.

Conditions necessary for profitable iron mining.—The value of an iron ore deposit depends as much on its geographic position, its relations to transportation and markets, and the facilities for mining, as it does on the quality of the

ore. Moreover if furnaces are to be erected for the manufacture of pig-iron, the distance of fuel, and of limestone for fluxing purposes, are most important points to consider. In determining the value of an iron deposit, therefore, four main subjects must be taken into consideration.

I. The quality and quantity of the ore.

II. The facilities for mining the ore.

III. The relations of the deposit to transportation and to markets.

IV. The relations of the deposit to fuel and limestone.

Conditions in northeastern Arkansas.—In the northeastern part of the state there are some isolated deposits of fairly good brown hematite which, if they had transportation facilities and markets, might be worked at a profit. The facilities for mining the ore in this region are good. It occurs on isolated hills and ridges rising from fifty to over three hundred feet above the surrounding drainage. It forms irregularly shaped bodies from two or three to probably over twenty-five feet in thickness, and often covering several acres, generally lying in a horizontal position and usually on or near the summits of the hills. Though limited in both lateral and vertical extent, the ore that is in any one place lies near the surface and could be easily mined. The nearest means of transportation for the ore of northeastern Arkansas is the Kansas City, Fort Scott and Memphis Railway, which is from 8 to 20 miles distant from the more important deposits. The Black River flows through the northeastern part of the state and in some localities freight might be shipped down it to the White River and thence to the Mississippi. The transportation facilities, however, cannot at present be considered as good, since, unless a branch road were built, a haul by wagons of from 8 to 20 miles would be necessary to reach either the railway or the river. The nearest coking coal to the iron deposits of northeastern Arkansas is that of western Arkansas and of Indian Territory, at distances by rail varying from 225 to over 400 miles. Good hardwood, however, fit for making charcoal, is plentiful in the vicinity of

the ore, and a fairly pure limestone can also be obtained in the same region.

In consideration, therefore, of the combination of a fairly good ore with a cheap charcoal, made from the timber of the region, and with limestone in the immediate vicinity, there is a possibility of a limited iron industry in northeastern Arkansas.

Conditions in northwestern Arkansas.—The ores in the northwestern part of the state, aside from any question of quality, are in too small quantities to be profitably worked.

Conditions in the Arkansas Valley.—In the Arkansas Valley the ores are too poor in quality and occur in too small quantities to be of any value as sources of iron.

Conditions in the Ouachita Mountains.—In the Ouachita Mountains the only ores yet found in large quantities are of low grade. The deposits dip steeply and would be expensive to mine. The nearest railways are from seven to, more generally, over twenty miles and often over forty miles distant. Limestone is scarce and often altogether absent in the Ouachita Mountains, and there is no coal nearer than the Arkansas Valley, with which region the Ouachita Mountains have no direct railway connection. There is, however, a large amount of timber, and with cheap charcoal fuel there is always at least a possibility of the future utilization of the better class of the ores. The industry, however, would never be an important one, and could only be carried on under the most favorable conditions of transportation and markets, conditions which at present are far from being realized.

Conditions in southern Arkansas.—In the southern part of the state the Tertiary brown hematites occur over considerable areas, but the ores which are of sufficiently good quality to use are so scattered that it is somewhat doubtful whether enough can be found in one place to permit important mining. Large deposits of poor ore frequently occur in this region, but they are of too low grade to be of value. The better ores are mostly from eight to fifteen miles from the nearest railway transportation, which is the St. Louis, Iron Mountain and Southern Railway or the St. Louis and Southwestern Rail-

way. Limestone would have to be brought, in most cases, from distances varying from fifty to a hundred miles. The ores are near the surface, however, and easily mined; and there is a large amount of timber fit for making charcoal in the vicinity; so that it is not impossible, in view of these advantages, that a small iron industry might, under favorable conditions, be supported on the better grades of ores of the region. The good ores are scarce, however, and under any circumstances the industry would be small.

Conclusion.—The commercial possibilities of the Arkansas iron regions may be briefly stated as follows:

The ores are mostly brown hematites, though small quantities of spathic and magnetic ores also occur. Most of the brown hematites, if not all, are non-Bessemer in character, the phosphorus ranging generally over 0.05 per cent; the iron ranges from 35 per cent to rarely over 55 per cent; the silica is usually, though not always, high, ranging from 2 per cent to over 75 per cent; the sulphur ranges from 0.04 to over 1 per cent; there is usually a trace of manganese and sometimes enough to allow the ore to be classed as a manganiferous iron ore; none of the ores, except that of Magnet Cove, have yet been found to contain appreciable quantities of titanium. The only ores in the state that could, even under the most favorable circumstances, be worked on a commercial scale are some of those in northeastern Arkansas and a few of the deposits of the Ouachita Mountains and of southern Arkansas. Of these three regions, northeastern Arkansas is the only one which offers favorable conditions for iron mining and manufacture, and even there the industry, if established, would be limited.

The conclusion to be drawn, therefore, is that the quality and the quantity of the Arkansas ores, the position of the deposits as regards transportation, the distance of the markets, and the proximity of much better ores in Missouri, all point to the fact that there is, at present, no good field for an iron mining industry in Arkansas except possibly in the northeastern part of the state.

CHAPTER II.

THE IRON DEPOSITS OF NORTHEASTERN ARKANSAS.

(Lawrence, Sharp, Fulton and Randolph counties.)

THE LOCATION OF THE DEPOSITS.

The iron ores of northeastern Arkansas occur mostly in the counties of Lawrence, Sharp, Fulton and Randolph, in the hilly country comprising the valleys of the Black River and its tributaries, the Strawberry, Spring and Eleven Points Rivers. This region includes an area over 50 miles long in an east and west direction, and about 35 miles wide in a north and south direction. The ore does not occur continuously throughout it, but exists as isolated deposits separated by much greater areas destitute of ore.

THE GEOLOGIC RELATIONS OF THE DEPOSITS.

The ores occur with a series of cherts, limestones and sandstones which form a part of the Lower Silurian series of northern Arkansas. The exact position of these rocks in the Lower Silurian is somewhat doubtful, but, from the studies of the State Geologist and Prof. H. S. Williams, it is probable that they belong in or below the Calciferous horizon. They dip under the saccharoidal sandstone and the Izard and St. Clair limestones which represent the upper members of the Lower Silurian system in the Batesville manganese region to the south of the iron region.*

THE NATURE OF THE ORES.

The iron ores of northeastern Arkansas all belong to the class of hydrous sesquioxides of iron, known as limonite, brown

*The geologic relations of these rocks are more fully discussed in the Annual Report of the Geological Survey of Arkansas for 1890, Vol. I, pp. 112-116.

hematite or simply "brown ore." Seventeen analyses of these ores, made by the Geological Survey, Prof. A. E. Menke, Chemist, are given in the accompanying table. It will be seen that the amount of iron varies from 23 to 58 per cent. In samples 1, 2, 11, 12 and 15 it is over 50 per cent, and is good for a brown hematite ore. The percentage of silica also varies considerably. Samples 1, 2, 3, 11 and 12, are low in silica; samples 6 and 7 are rendered undesirable on account of their high percentages of silica; while samples 4, 5, 9, 10, 13 and 14 are practically ruined by their high contents of this ingredient.

In phosphorus also the samples are variable, some being low enough to be classed as Bessemer, while others are too high. An ore is too high in phosphorus to be used for Bessemer steel if it contains more than about 0.05 per cent of that ingredient (see pages 8 to 10). It will be seen that several of the samples contain less than that amount. Sufficient analyses, however, have not been made of the ore on any one property to state that the whole deposit would be low enough in phosphorus to make Bessemer steel, as it is perfectly possible that a sample from one part of a deposit may be low in phosphorus, while another from a few yards off may be high. The average contents of a deposit in phosphorus can only be determined by carefully prospecting and stripping the ore and making numerous analyses, all of which has been beyond the means and the time of the Survey. The low phosphorus, therefore, in some of the analyses can be regarded only as a valuable indication and not necessarily conclusive as to the quality of the whole deposit.

The sulphur is not excessively high in any of the samples analyzed.

Considering all the constituents of the ores, it may be said that samples 1, 2, 3, 11, 12 and 15 are good ores, while the rest of the samples represent ores more or less injured or even ruined by the low percentage of iron or by excessive quantities of impurities.

The ores vary much in physical character. In color they

range from light yellow to chocolate brown, or even almost black, and are often coated with a glossy black film. They often contain considerable quantities of sand which can be seen in grains scattered through the mass; and in the more siliceous varieties the sand increases in quantity until the ores merge into a ferruginous sandstone. Between the pure ore and the ferruginous sandstone there are all degrees of admixture. Sometimes the ore is massive and solid, at other times porous and honeycombed, while not infrequently it occurs as geodes, commonly called "iron pots," from an inch to a foot

Analyses of iron ores from northeastern Arkansas.

Number.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyzed by
	LAWRENCE COUNTY.						
1	Coffman tract, 17 N., 1 W., Sec. 17, S. ½, S. E	55.75	5.20	0.041	0.212	A little	Menke
2	Holloway tract No. 1, 16 N., 2 W., Sec 6, S. E.	58.91	7.08	0.028	0.198	"	"
3	Holloway tract No. 2, 17 N., 3 W., Sec. 35, N. E , S. E.	45.49	8.47	0.007	0.815	"	"
4	Cazort tract, 16 N., 2 W., Sec. 6, N. W., S. W......	41.71	28.26	0.014	0.232	"	"
5	Holloway & Collins tract, No. 1, 16 N., 3 W., Sec. 12, S. E	49.44	25 85	0.028	0.479	"	"
6	Holloway & Collins tract No. 2, 16 N., 3 W., Sec. 12, W. ½, W. ½	47.99	15.08	0.088	0 054	"	"
7	Wasson tract, No. 1, 17 N., 3 W., Sec. 26, S. ½........	41.58	16.26	0.193	0.095	"	"
8	Sloan tract, 17 N., 3 W., Sec. 28, W. ½, N. E	40.10	12.54	0.042	0.687	"	"
9	Strawberry or Cathaytown, 16 N., 3 W., Sec. 12, S. E.	36.30	30.87	0.041	0.205	None.	"
10	" " " " " "	27.85	52.58	0.284	0.034	"	"
	SHARP COUNTY.						
11	Collins tract, 16 N., 4 W., Sec. 8, S. W..............	58.91	2.46	0.083	0 109	Trace.	"
12	Wasson tract No. 2, 16 N., 4 W., Sec. 13, E. ½, S. E ..	54.70	2.80	0.021	0.458	None.	"
13	Big Creek and Reed's Creek divide, 16 N., 4 W., Sec. 36, N. ½	23.67	58.12	0.306	0.178	"	"
	FULTON COUNTY.						
14	Deadrick tract, 20 N., 6 W., Sec. 1.....	44.97	21.40	0.031	0.109	"	"
	RANDOLPH COUNTY.						
15	Near Ravenden Springs..................	50.49	12.60	0.041	0.102	A little	"
16	Odom tract, 18 N., 1 W., Sec. 18, N. E., N. E........	44 44	11.83	0.021	0.157	"	"
17	Iron Bank, 21 N. 3 W., Sec 8, N. E , S. W.	49.97	14.58	0.014	0.082	Trace.	"

or more in diameter. Elsewhere the ore occurs as the cement of a brecciated chert.

THE MODE OF OCCURRENCE OF THE ORES.

The general character of the region in which the iron ores of northeastern Arkansas occur, is that of a rolling country with hills and ridges rising from one to over three hundred feet above the surrounding drainage, and separated by flat river and creek bottoms. The hills and ridges often rise abruptly from the lowlands and the ridges follow a circuitous course for many miles across the country. Such ridges are well seen between the Spring and the Eleven Points Rivers in Randolph county, between Big Creek and Reed's Creek in Sharp county, and elsewhere.

The iron ore usually occurs on or near the tops of the hills and ridges, though more rarely it is lower down on the slopes. The lower parts of the hills and ridges are composed of a blue limestone which underlies the larger portion of the low country and is the predominating rock of the region. This bed and also all the other rocks of the region are practically horizontal, though they sometimes dip gently to the south. A thickness of limestone of over 200 feet is often exposed on the slopes of the hills, and, as it still underlies the lowlands, it is probably thicker. Above the limestone on the slopes of the hills comes a sandstone which generally forms the summit, at least of the higher points, and varies in this position from a few feet to almost if not quite 100 feet in thickness. Sometimes the sandstone does not occur, and the hills are capped with a gray chert which often partakes of the nature of a sandy quartzite. In the cases where both the sandstone and the chert occur in the same locality, the chert underlies the sandstone and overlies the blue limestone; where the chert is wanting the sandstone comes into direct contact with the limestone. It is noticeable that, though the limestone is apt to contain cherty masses anywhere through it, the formation becomes more and more cherty towards the top. It seems probable that when the chert intervenes

between the sandstone and the limestone, it simply represents an unusually large development of this cherty character of the top of the limestone. This would account for its sudden appearance and disappearance, since sometimes it has a thickness of probably 75 feet or more, while elsewhere it is wanting altogether, and the sandstone comes into direct contact with the underlying limestone.

Where the sandstone has been eroded from the hills and ridges and the chert covers the highest points, the summits have the characteristic rough appearance of a surface covered with broken masses of rock. Not infrequently the chert is abruptly cut off by a protrusion of limestone which comes to the top of the hill and locally forms the crest, while beyond, along the summit, the chert appears again. This sequence of outcrops is a natural result when it is considered that the chert exists simply as large pockets and lenticular layers in the limestone, and may be cut out by that rock at any point.

The iron ore occurs in both the chert and the sandstone; and as either one or the other of these rocks usually forms the crests of the hills and ridges, the ore is generally near the summits. It does not form a continuous bed over any very large area, but occurs in more or less isolated basin-shaped deposits, varying from a few square yards to several acres in extent and from two or three feet to probably over twenty-five feet in thickness. The section in figure 1 represents a typical case of the iron deposits of northeastern Arkansas, as exemplified in Iron Mountain on the Collins tract in Sharp county. This tract will be more fully described later in the present chapter.

In following along any of the ridges in the iron district a series of such basin-shaped pockets as have just been described are seen, separated along the ridge by areas of barren sandstone or chert. Sometimes the ore is comparatively pure, at other times it simply forms the coloring matter and cement of a ferruginous sandstone or binds together the fragments of a chert breccia; and almost always more or less sandy impurities can be seen in it. Sometimes the ore forms interbedded,

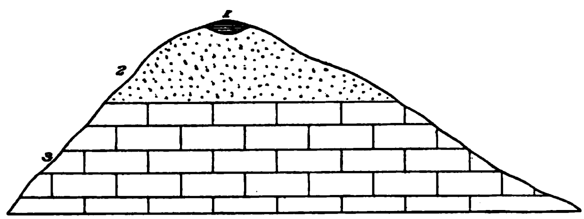

Figure 1. *Section across Iron Mountain on the Collins tract, Sharp county, showing the mode of occurrence of the iron ore.*

1. Iron ore (limonite.)
2. Sandstone.
3. Limestone.

Horizontal scale: 1 inch=½ mile. Vertical scale: 1 inch=100 feet.

alternating layers with a ferruginous sandstone, or occurs in bunches in the sandstone or chert. A common occurrence is a chert bed cut by a network of bunches and connecting seams of ore.

Frequently where the sandstone or chert is soft, the rock has decayed, forming a red clay in which the masses of ore are imbedded. Such deposits often afford a good soil and at the present time many of the iron ore tracts are cultivated as farms, and the lumps of ore are constantly being plowed up. This is especially well seen in the neighborhood of Smithville in Lawrence county, and around Calamine in Sharp county. Occasionally also the ferruginous waters from springs in the iron ore hills have cemented the sand and gravel in the creek beds, forming a ferruginous conglomerate, which is of course of much later age than the iron ore in the hills.

THE COMMERCIAL VALUE OF THE DEPOSITS.

The facilities for mining iron ore in northeastern Arkansas are fairly good. The ore, occurring as it does on the tops of isolated hills and ridges, though limited in both vertical and lateral extent, could be easily mined. The nearest means of transportation is the Kansas City, Fort Scott and Memphis Railway, which is from eight to twenty miles distant from the more important deposits. In some cases freight could be shipped down the Black River to the White River, and thence

to the Mississippi, but here also a haul by wagons of from ten to twenty miles would be necessary. The nearest coking coal to the iron deposits is that of western Arkansas and of Indian Territory at distances by rail of from 225 to over 400 miles. Good hardwood fit for making charcoal is plentiful in the vicinity of the ore, and a fairly pure limestone could also be obtained in the same region. As already stated, the ore of some of the deposits is too poor in quality to be of any value, but the ore of other deposits combines a fairly good quality with sufficient quantity to allow it to be mined.

In view of all these conditions it may be said that there is a chance of the profitable working of some of the iron deposits of northeastern Arkansas.

Below are given descriptions of the individual properties in the iron region of northeastern Arkansas.

LAWRENCE COUNTY.

General features.—The iron ores of Lawrence county are mostly west of the Black River, in the western part of the county. They extend from near Black Rock on the Black River, west into Sharp county and south to and beyond the Strawberry River. This area includes most of the deposits that are known, though others of less importance are found elsewhere in the county.

The J. W. Coffman tract.—The Coffman tract is in 17 N., 1 W., section 17, the south half of the southeast quarter, about a mile west of Black Rock. A brown hematite ore occurs in loose masses here associated with fragments of chert in a red and white clay. It is found over an area of probably six or seven acres. The deposit is so much concealed by soil that it is impossible to determine accurately its size and extent without more prospecting than has been done. The only opening that has been made is a small pit about six feet deep showing masses of ore in the clay. Some of the ore contains siliceous pebbles and this may be, in part at least, a later deposit than the ore free from pebbles.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of iron ore from the Coffman tract, Lawrence county.

Iron	55.75
Silica	5.20
Phosphorus	0.041
Sulphur	0.212
Manganese	a little.

The analysis shows the ore to be of good quality, but the quantity of it on the property has yet to be proved.

The S. P. Holloway tract No. 1.—This is one of the several tracts of iron ore land owned in this region by Mr. S. P. Holloway of Black Rock. It is in 16 N., 2 W., section 6, the southeast quarter. The brown hematite ore occurs here in loose masses in the soil on the summit of a hill. It is associated with fragments of sandstone and quartzite, and the exposed masses of ore have probably been set free during the disintegration of these rocks, in which they were probably originally held. The ore is sometimes sandy and is occasionally found adhering to masses of sandstone. It sometimes occurs as hollow "pots," and at other times as a massive ore with a banded; agate-like structure. A few small prospecting pits show masses of ore imbedded in the red soil.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of iron ore from the S. P. Holloway tract No. 1, Lawrence county.

Iron	53.91
Silica	7.08
Phosphorus	0.028
Sulphur	0.198
Manganese	a little

The analysis shows the ore to be of very good quality. It is comparatively high in iron, exceptionally low in phosphorus and comparatively low in silica. This analysis, however, cannot be considered as representing the quality of the whole deposit. The property is heavily covered with soil, and when the sample for the analysis was taken only a limited part of the

whole ore bed was accessible. To test the deposit properly it should be stripped in a large number of places and numerous samples should be taken for analysis. In this way both the quality and quantity of the ore could be determined, a thing which in the present unprospected condition of the property it is impossible to do.

The Cazort tract.—The Cazort tract is in 16 N., 2 W., section 6, the northwest quarter of the southwest quarter, and in section 7, the northeast quarter of the southeast quarter. It is close to the last mentioned property and the ore occurs under very much the same conditions as on that tract, except that it is more sandy and, therefore, contains a larger percentage of silica, as shown by the following analysis by A. E. Menke:

Analysis of iron ore from the Cazort tract, Lawrence county.

Iron	41.71
Silica	28.26
Phosphorus	0.014
Sulphur	0.282
Manganese	a little

The analysis shows the ore to be low in iron and injuriously high in silica.

The Holloway and Collins tract No. 1.—The Holloway and Collins tract No. 1 is in 16 N., 3 W., section 12, the southeast quarter, and is locally known as Iron Mountain. The brown hematite crops out for a distance of half a mile on the summit of a ridge running in a general north and south direction. The base and lower slopes of the ridge are composed of blue limestone lying almost horizontally, while sandstone with more or less chert and quartzite appears on the upper part The sandstone is in some places white, and in others rusty brown from the presence of iron. The ore occurs in isolated basins or in large irregular pockets in the sandstone, and in following along the top of the ridge ore may be found in one place and perhaps a few yards further on sandstone crops out, to be cut off by ore again beyond, thus causing an alternating series of outcrops of ore and sandstone. So little prospecting has been done on the property that it is impossible to determine the

the thickness of the deposit or, in fact, anything more than its most general features.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the Holloway and Collins tract No. 1, Lawrence county.

Iron	49.44
Silica	25.85
Phosphorus	0.028
Sulphur	0.479
Manganese	a little

The analysis shows the ore to contain an injuriously large percentage of silica.

The Holloway and Collins tract No. 2.—The Holloway and Collins tract No. 2 is in 16 N., 3 W., section 12, the west half, and shows ore somewhat like that on the last property. It is covered with so much soil, however, that it is impossible to determine accurately the extent of the deposit. A pit about twenty feet deep was sunk at this place some years ago. It is now mostly filled with earth, but the upper six or seven feet are still open. It shows alternating layers of ore and ferruginous sandstone, the thickest layer of solid ore seen being about two feet. Sometimes layers and pockets of red clay occur in the ore. The ore dips apparently at about 30° to the southwest, but this may simply be due to a local slip in the surface rocks. It is probable that further prospecting on this property would show a considerable series of alternating layers of sandstone and ore.

The following analysis by A. E. Menke shows the composition of the ore on this property:

Analysis of iron ore from the Holloway and Collins tract No. 2, Lawrence county.

Iron	47·99
Silica	15.08
Phosphorus	0.083
Sulphur	0.054
Manganese	a little.

This analysis shows the ore to be fairly good in its contents

of iron, somewhat injured by the high percentage of silica, and to contain too much phosphorus to be classed as a Bessemer ore.

The S. P. Holloway tract No. 2.—The Holloway tract No. 2 is north of the last mentioned property and in 17 N., 3 W., section 35, the northeast quarter of the southeast quarter. A porous brown hematite, often in the form of "iron pots," occurs here in a red and brown clay in the bluff of a small creek. The masses of ore, which are sometimes two or three feet in diameter, often form horizontal layers in the clay. A pit said to be twenty feet deep was sunk here some time ago, but it is now filled up to within eight feet of the surface. The exposed sides of the pit show a face of ore in red and gray clay over five feet thick. This is underlain by clay, below which more ore is said to have been found in the old pit. About ten feet of ore altogether is said to have been exposed.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of ore from the S. P. Holloway tract No. 2, Lawrence county.

Iron	45.49
Silica	8 47
Phosphorus	0.007
Sulphur	0.815
Manganese	a little.

The analysis shows the ore to be somewhat low in iron, but good in other respects.

The Wasson tract No. 1.—The Wasson tract No. 1 is in 17 N., 3 W., section 26, the south half. This property is on the continuation of the same ore belt as the last mentioned property, and shows ore occurring under somewhat the same conditions. The ore is often composed of geodes, or "pots," of brown hematite from one to six inches in diameter and held together by a ferruginous cement.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of iron ore from the Wasson tract No. 1, Lawrence county.

Iron	41.58
Silica	16 26
Phosphorus	0.198
Sulphur	0.095
Manganese	a little.

The analysis shows the ore to be low in iron and high in silica, though other samples from this property might give better results.

The Moore tract.—The Moore tract is in 17 N., 3 W., section 22, the southeast quarter of the southeast quarter. It shows ore occurring under much the same conditions as on the Wasson tract, which lies northwest of it.

The W. C. Sloan tract.—The Sloan tract, commonly known as High Peak, is in 17 N., 3 W., section 28, the west half of the northeast quarter. High Peak is a small knob rising from the crest of a ridge and reaching between two and three hundred feet above the surrounding drainage. The lower part of the hill is mostly limestone, while the crest of the knob is capped with chert, which outcrops in a loose broken mass. Fragments of brown hematite occur with the loose chert on the summit, and have undoubtedly been derived from a small pocket of ore in that rock. One small opening about three feet deep has been made. The ore is in small quantities, the fragments occurring scattered over only about half an acre.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the W. C. Sloan tract, Lawrence county.

Iron	40.10
Silica	12.54
Phosphorus	0.042
Sulphur	0.637
Manganese	a little

The analysis shows the ore to be low in iron.

Strawberry, or Cathaytown.—The village of Strawberry, also known as Cathaytown, is on the south side of the Strawberry River, in 15 N., 3 W., section 5. A brown ferruginous sandstone covers several of the hills in the village, forming numer-

ous rounded, rocky knobs, and is commonly mistaken for iron ore. Occasionally a few small masses of a sandy brown hematite occur in the rock, but the vast bulk of what is commonly supposed to be ore is simply a rusty sandstone, of no value whatever as an iron ore. Similar materials exist in many other places near Strawberry.

The following analyses by A. E. Menke show the composition of this material:

Analyses of iron ore from Strawberry, Lawrence county.

Iron	36.30	27.35
Silica	30.87	52.58
Phosphorus	0.041	0.284
Sulphur	0.205	0.034
Manganese	none	none

These analyses show the so-called iron ore of Strawberry, or Cathaytown, to be so low in iron and so high in silica that it is worthless as a source of iron.

SHARP COUNTY.

General features.—The iron ores of Sharp county, so far as known, lie mostly south of the Strawberry River, in the southern part of the county, though other deposits occur north of this area.

The Collins tract.—The Collins tract is in 16 N., 4 W., section 8, the southwest quarter. It is locally known as Iron Mountain, which is the top of a ridge rising almost 200 feet above the surrounding drainage. The lower part of the hill, for about 90 feet from the base, is composed of the blue limestone common to the region. The upper 85 feet are composed of sandstone, often assuming a quartzitic nature. The ore occurs in fragments on the summit, and is associated with the sandstone, from which the masses of ore have been derived. The ore covers about two acres and is found more sparingly beyond these limits. It evidently represents a basin-shaped deposit in the sandstone. A pit, mostly filled up, is said to have been ten feet deep and to have gone through ore all the the way. The ore is a brown hematite, often occurring as a mass of small nodules, the size of a pea or larger, with a fibrous

structure, radiating from the centre. Elsewhere the ore is simply the common porous and honeycombed brown hematite.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the Collins tract, Sharp county.

Iron	58·91
Silica	2.46
Phosphorus	0.088
Sulphur	0.109
Manganese	trace

The analysis shows a very good ore for non-Bessemer purposes, though the phosphorus is too high to permit it to be used for Bessemer steel. The quantity of the ore, however, from a commercial standpoint has yet to be determined.

The Wasson tract, No. 2.—The Wasson tract No. 2 is in 16 N., 4 W., section 13, the east half of the southeast quarter. The land here is mostly under cultivation and heavily covered with soil. The ore occurs as masses in red clay and is only seen where it has been plowed up. The property is only half a mile north of the Bevens Bloomary, where iron was made before 1860 (see page 2), and a part of the ore used in the bloomary is said to have been mined on this tract. At present the old pits have been filled up and but little can be seen of the ore.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the Wasson tract No. 2, Sharp county.

Iron	54.70
Silica	2.80
Phosphorus	0.021
Sulphur	0.458
Manganese	none

The analysis shows the ore to be of very good quality, high in iron and low in silica and phosphorus, but the quantity of the ore is doubtful. An ore that seems to be similar to that on the Wasson tract occurs in 16 N., 4 W., section 24, the east half of the northeast quarter.

The Big Creek and Reed's Creek divide—Big Creek and

Reed's Creek both rise in the southern part of Sharp county and flow east, emptying into the Strawberry River in Lawrence county, a few miles east of the dividing line between the two counties. A long, narrow ridge, often rising over 100 feet above the surrounding drainage, forms the divide between the waters of the two creeks. It is composed of the blue limestone in its lower parts, and is capped with a sandstone varying from white to rusty brown in color, and ranging from ten to twenty feet or more in thickness. This divide is sometimes broken longitudinally into two or more parallel ridges. In following along the summit of any of these ridges it is found that the character of the sandstone varies much in different places, often changing abruptly from a pure white rock to one stained dark brown by iron, the latter dark rock representing simply local, isolated patches in the white variety. This ferruginous sandstone is often mistaken by the people living in the vicinity for iron ore, but it contains too much sand and too little iron to be of any value as such. Occasionally small masses, seams or pockets of a genuine ore in the form of a brown hematite occur in the ferruginous sandstone, but this is in only very small quantities and could not be profitably separated. The great mass of the so-called ore is simply a rusty sandstone.

Such deposits are well seen in several places on the Big Creek and Reed's Creek divide, especially in 16 N., 4 W., section 36, the north half, and in section 25, the south half. The following analysis, by A. E. Menke, of a sample of the material from the first named locality shows its composition:

Analysis of iron ore from the Big Creek and Reed's Creek divide, Sharp county.

Iron	23.67
Silica	58.12
Phosphorus	0.306
Sulphur	0.178
Manganese	none

The analysis shows the material to be too low in iron and too high in silica to be of any value whatever as an iron ore.

FULTON COUNTY.

General features—The iron ores of Fulton county, so far as known, occur mostly in the region between Spring River on the east and a few miles beyond the town of Salem on the west. Among the best known localities is the Deadrick tract.

The Deadrick tract.—The Deadrick tract is in 20 N., 6 W., section 1. The ore is a brown hematite and occurs in association with a bed of chert on the crest and upper slopes of a limestone ridge. The ore occurs mostly in fragments on the surface, covering probably about seven acres, and is mixed with angular fragments of gray or rusty brown chert. In some places, however, where it is exposed in place, its original mode of occurrence is found to be as masses and pockets in the chert, sometimes also as the cement of a chert breccia. Near the base of the deposit the ore becomes more and more cherty until it is finally cut out altogether by solid chert, and this rock in turn is soon replaced by the underlying limestone. The ore represents an irregular and isolated body in the chert, probably not more than twenty feet thick anywhere and much thinner in some places, while the chert itself represents an irregular bed in the upper part of the limestone.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of iron ore from the Deadrick tract, Fulton county.

Iron	44.97
Silica	21.40
Phosphorus	0.081
Sulphur	0.109
Manganese	none

The analysis shows the ore to be high in silica, though some of the ore on this tract is of better quality than that represented by the analysis.

RANDOLPH COUNTY.

General features.—Iron ores in the form of brown hematite occur in many parts of Randolph county, especially in the country between Spring River and Eleven Points River, and also

in the northeastern part of the county near the Arkansas and Missouri boundary line, but so far as yet discovered the deposits are all too small and often too poor in quality to be of any commercial value.

Ravenden Springs.—The village of Ravenden Springs is in 19 N., 2 W., section 7. Though no iron ore occurs in the immediate neighborhood of the village, it is found in several places short distances to the east and south, on the divide between Spring River and Eleven Points River. The main part of this divide in the region in question is a long tortuous ridge running in a general northwest and southeast direction and rising from 200 to 300 feet or more above the surrounding drainage. The lower part of the ridge, for sometimes 200 feet from the base, is composed of the blue limestone already described (page 23). This rock becomes cherty towards the top, and the upper part of the bed is composed largely of chert for a thickness of probably, in some places, 75 feet or more. The chert usually forms the crest of the ridge, giving it the rough rocky appearance of a chert region. On the higher parts of the ridge, however, the sandstone, which belongs above the chert, often appears and forms the summit. Occasionally the chert is absent and the sandstone and limestone come into direct contact, as already explained on page 23. Most of the iron ore occurs on the summit of the ridge, as pockets in the chert, the deposits forming, on account of their dark color, a striking contrast with the light gray chert which surrounds them on all sides.

About a mile and a half east of Ravenden Springs a small pit has been made in a deposit of brown hematite. The chert has partly decayed and the ore occurs in masses and layers in a brown and white clay which has resulted from this decomposition.

The following analysis by A. E. Menke shows the composition of this ore:

Analysis of iron ore from near Ravenden Springs, Randolph county.

Iron	50.49
Silica	12.60
Phosphorus	0.014
Sulphur	0.102
Manganese	a little

The analysis shows an ore of fairly good quality. The quantity of the ore, however, is uncertain, as very little prospecting has been done, but it is probably limited.

Southeast of this locality, for five or six miles along the crest of the ridge, similar or even smaller deposits occur. Sometimes they show small quantities of ore, at other times they are simply rusty chert.

Jackson.—The old village of Jackson is about eight miles southeast of Ravenden Springs and on the divide between Spring River and Eleven Points River, already described. Less than a mile north of the village and in 17 N., 1 W., section 2, on the old military road, a few scattered lumps of brown hematite, associated with fragments of chert, occur on the upper slopes of a hill. The ore is in very small quantities.

The B. B. Odom tract.—The Odom tract is in 18 N., 1 W., section 18, the northeast quarter of the northeast quarter. Masses of iron ore associated with fragments of chert occur here, but the deposit has not been prospected and is so covered with soil that it is difficult to determine anything about its extent. Some of the ore contains rounded siliceous pebbles, and occasionally it forms the cement of a mass of pebbles and sand. Such materials may possibly represent a later formation than the other ore and, if so, the iron in them has probably been derived from the older ore.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the Odom tract, Randolph county.

Iron	44.44
Silica	11.83
Phosphorus	0.021
Sulphur	0.157
Manganese	a little

The analysis shows the ore to be somewhat low in iron but good in other respects.

Iron ore somewhat similar to that on the Odom tract also occurs in 18 N., 1 W., section 6, the west half of the southwest quarter.

Iron Bank.—What is locally known as Iron Bank is in 21 N., 3 W., section 8, the northeast quarter of the southwest quarter, about a quarter of a mile south of the Arkansas and Missouri boundary line and about fifteen miles east of the town of Mammoth Spring. The ore is a brown hematite and occurs in association with chert on the end of a ridge. The lower part of the ridge is composed of the blue limestone, and the chert occurs with a thickness of about thirty feet on the summit. The fragments of ore cover about five acres on the top of the ridge and the deposit represents a local body of ore in the chert. Occasionally the ore forms the cement of a chert breccia.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of iron ore from Iron Bank, Randolph county.

Iron	49 97
Silica	14 58
Phosphorus	0 014
Sulphur	0 082
Manganese	trace

The analysis shows the ore to be fairly good in its percentage of iron, but somewhat high in its percentage of silica.

CHAPTER III.

THE IRON DEPOSITS OF NORTHWESTERN ARKANSAS.

(Carroll, Washington and Madison counties.)

THE LOCATION OF THE DEPOSITS.

The iron ores of northwestern Arkansas are mostly in Carroll county, in the vicinity of the town of Berryville. These ores were once mined to supply the old Beach Iron Works already described on page 3.

Small quantities of impure ore also occur in many parts of Washington, Madison and other counties in northwestern Arkansas.

THE GEOLOGIC RELATIONS OF THE DEPOSITS.

The iron ores of Carroll county occur mostly in Lower Silurian chert not unlike that in the iron region of northeastern Arkansas, and probably in the same or nearly the same geologic horizon. It is possible that some deposits may also exist in the Boone chert of the Lower Carboniferous series. The iron ores of Washington and Madison counties occur in Lower Carboniferous sandstones, and the geology of such ores is further mentioned in the next chapter, on the Iron Deposits of the Arkansas Valley.

THE NATURE OF THE ORES.

The iron ores of northwestern Arkansas, like those of northeastern Arkansas, are all, or nearly all, brown hematites (limonites). They are mostly impure and are often injured in quality by their low percentage of iron or their high percentage of silica, or by both these defects. As will be seen by the accompanying table, analyses Nos. 1 and 2 are low in silica, but Nos. 3 and 4 are so high in that constituent and so low in iron that the

ores represented by them are worthless. Many of the so-called iron ores of Carroll county are simply ferruginous cherts, containing from 10 to 30 per cent of iron and from 20 to over 50 per cent of silica, and are therefore of absolutely no value as ores of iron. Most of the Washington and Madison county "ores" are simply ferruginous sandstones of even poorer quality.

Analyses of iron ores from northwestern Arkansas.

No.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese	Analyzed by
	CARROLL COUNTY.						
1	Bobo tract, near Berryville..........	47 83	5.86	0.028	0.287	A little	Menke.
2	Mack Thomas tract, near Berryville..	45.01	6.82	0.035	0.301	A little	Menke.
3	Brooks tract, near Berryville........	21 96	50.42	0.299	4.486	None	Menke.
	WASHINGTON COUNTY.						
4	Near Tolu, 14 N., 33 W., sec. 16, N.W	13 62	60.80	0 046	......	4.03	Brackett.

THE MODE OF OCCURRENCE OF THE ORES.

The iron ores of Carroll county occur as pockets in chert in a manner similar to some of those of northeastern Arkansas, already described. The pockets are extremely small, however, and the ore deposits often consist simply of parts of the chert bed cut by a network of thin seams and bunches of ore. The chert has usually decayed on the surface, and the ore as now found occurs in lumps, associated with lumps of chert, in a red clay which has resulted from this decomposition. The iron ores of Washington and Madison counties occur simply as thin seams, at the most a few inches thick, cutting the sandstone in various directions. Other ores of these two counties are simply sandstones impregnated with iron.

THE COMMERCIAL VALUE OF THE DEPOSITS.

It is evident from what has been said above that, so far as yet known, the iron ores of Carroll, Washington and Madison counties are, even where the quality is fairly good, in too

small quantities to be of any commercial value. It might be said in contradiction to this statement that the ores of Carroll county were in sufficient quantities and good enough to be used at the old Beach Iron Works. (See page 3.) This is true, but the only reason that they were used at those works was because at the time the Beach bloomary was in operation, Carroll county was so far from means of transportation and from sources of supply of pig-iron or iron implements, that it was difficult to obtain such materials. Under these conditions it was possible to use at a profit even a low grade and expensively mined iron ore when it occurred in the immediate vicinity. At the present time, however, with the existing railway facilities and the numerous large iron furnaces in adjoining states, such an enterprise could not possibly be carried on successfully.

Below are given descriptions of several of the best known iron ore localities of northwestern Arkansas.

CARROLL COUNTY.

General features.—The iron ores of Carroll county occur in the central part of the county, mostly within a radius of three or four miles of Berryville.

The J. A. Bobo tract.—The Bobo tract is about a mile northwest of Berryville. The ore is a brown hematite and occurs on the west slope of a ridge, near the summit. It is associated with gray chert, and represents simply a pocket of ore in that rock. It usually contains masses of chert and sometimes forms the cement of a chert breccia. Fragments of loose ore are scattered on the surface of the ground over an area of about three acres.

The following analysis by A. E. Menke shows the composition of the ore from the Bobo tract:

Analysis of iron ore from the J. A. Bobo tract, Carroll county.

Iron	47.88
Silica	5 36
Phosphorus	0.028
Sulphur	0.287
Manganese	a little

The analysis shows the ore to be of fairly good quality. The sample analyzed, however, was better than the average of the ore on the property.

Ore similar to that on the Bobo tract occurs on the Ferree tract to the south, and on the Shaver tract to the north and west of the Bobo property.

The Mack Thomas tract.—The Mack Thomas tract is in 20 N., 25 W., section 23, about three miles west of Berryville. The ore, which is the usual brown hematite, occurs in much the same manner as on the Bobo tract except that there is more ore exposed on the surface than at the latter place. The chert is more or less decomposed, and the ore occurs in a red clay which has resulted from this decay. The ore is generally badly mixed with chert and often blends into what is simply a rusty chert.

The following analysis by A. E. Menke shows the composition of the best of the ore on this property:

Analysis of iron ore from the Mack Thomas tract, Carroll county.

Iron	45.01
Silica	6.82
Phosphorus	0.035
Sulphur	0.301
Manganese	a little

The analysis shows the ore to be of fairly good quality though a little low in iron.

The Eph. Thomas tract.—The Eph. Thomas tract is four miles north of Berryville. A few small fragments of brown hematite occur in the soil with masses of chert. There is only a very small quantity of ore, not enough to be of any value. A rusty chert sometimes occurs on this property and is often mistaken for ore. It is of no value.

The Alexander Brooks tract.—The Alexander Brooks tract is four miles north of Berryville and near the Eph. Thomas tract. Masses of ore cover about three acres and frequently contain considerable quantities of chert and sand.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of iron ore from the Alexander Brooks tract, Carroll ccunty.

Iron	21.96
Silica	50.42
Phosphorus	0.299
Sulphur	4.486
Manganese	none

The analysis shows the ore to be so low in iron and so high in silica that it is worthless. The sulphur also is high.

The Harrison farm.—What is known as the Harrison farm is about a mile west of Berryville, on the north side of the old "wire road." Small masses of brown hematite, too few to be of any value, are mixed among the fragments of chert which cover a part of the property.

WASHINGTON AND MADISON COUNTIES.

General features.—Low grade iron ores in small quantities, and ferruginous sandstones and conglomerates, often mistaken for iron ores, similar to the material described in the next chapter as occurring in Crawford and other counties, occur in many parts of Washington and Madison counties, as well as in some of the other counties in the northwestern part of the state. They are of no commercial value and do not require further mention, as such deposits are fully described and shown to be worthless in the regions discussed in chapter IV. An analysis, by Dr. R. N. Brackett, of a sample of such a material from Washington county, 14 N., 33 W., section 16, the northwest quarter, near Tolu, sent to the Survey by Hon. T. B. Greer, of Tolu, gave the following composition:

Analysis of iron ore from near Tolu, Washington county.

Iron	18.62
Silica	60.80
Phosphorus	0.046
Manganese	4.08

The analysis shows the material to be too low in iron and too high in silica to be of any value as an iron ore.

CHAPTER IV.

THE IRON DEPOSITS OF THE ARKANSAS VALLEY.

(Van Buren, Conway, Pope, Yell, Johnson, Logan, Franklin, Sebastian, Scott and Crawford counties.)

THE LOCATION OF THE DEPOSITS.

Under the description of the iron deposits of the Arkansas Valley are included not only the deposits in the immediate valley of the river, but also those in the regions drained by the tributaries of that stream. In this group will be treated, therefore, the deposits of Van Buren, Conway, Pope, Yell, Johnson, Logan, Franklin, Sebastian, Scott and Crawford counties. The ore does not occur continuously throughout this area, but exists only in scattered deposits of small extent. Similar deposits also exist in Lonoke, Faulkner, White and Cleburne counties.

THE GEOLOGIC RELATIONS OF THE DEPOSITS.

The iron deposits of the Arkansas Valley, as defined above, are wholly in regions of Carboniferous and Lower Carboniferous rocks and are mostly deposits of that age. Some of the ores, however, are later deposits formed around the orifices of springs by the dissolving out and concentrating, through the medium of acidulated waters, of the iron originally disseminated through the rocks. Such deposits, therefore, may vary in age from pre-Cretaceous to those made in Recent times.

The deposits in the Carboniferous and Lower Carboniferous rocks are mostly interbedded lenticular layers or nodules of highly siliceous brown hematites or of carbonate ores, while many materials which are often mistaken for ores are simply the ferruginous sandstones characteristic of the above mentioned series of rocks. Both the ores and the sandstones are of too low grade to be used as sources of iron, and it is,

therefore, unnecessary to discuss further their relations to the geologic and structural features of the region, especially as these features have already been described in the report of the Survey on coal by Mr. Arthur Winslow,* and will be more fully discussed by him in a forthcoming report on the same subject, as well as by Mr. J. H. Means in a forthcoming report on the Barren Coal Measures.

The deposits around the mouths of springs are further discussed under the treatment of the mode of occurrence of the ores.

THE NATURE OF THE ORES.

The iron ores of the Arkansas Valley are mostly impure brown hematites, though small quantities of the carbonate of iron, known as siderite, spathic ore or clay-ironstone, also occur. Both varieties are very impure, and usually contain too much silica and phosphorus and too little iron to be of any commercial value. As will be seen by the accompanying table of analyses the iron ranges from less than 15 per cent to less than 40 per cent, the silica from 10 to over 60 per cent, and the phosphorus from 0.241 per cent to over 0.50 per cent. These figures are sufficient to condemn the ores without further discussion. Many of what are usually supposed to be iron ores are simply ferruginous sandstones of no value whatever as a source of iron. Under delusion as to their nature, however, many people have been led to believe that they possessed large bodies of iron ore when they had only a rusty rock.

Of course on many of the properties examined it would have been possible to select samples of ore that would have proved by analysis to be of much better quality than the samples of which analyses are given here, but the samples that were taken were so selected as to represent as nearly as possible the average quality of the ore as it would be mined in large quantities. This, of course, was the only means of obtaining an intelligent idea of the quality of the deposits as a whole.

*Annual Report of the Geological Survey of Arkansas for 1888, Vol. III.

Analyses of iron ores from the Arkansas Valley.

Number.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyzed by.
	VAN BUREN COUNTY.						
1	McGruder tract, near Choctaw...............	24.40	40.44	0.276	0.178	A little	Menke.
2	Lick Mountain, " "	20.98	18.78	0.524	0.128	" "	"
	POPE COUNTY.						
3	Guest tract, near Russellville................	24.40	46.86	0.242	0.164	Trace	Menke.
4	Bowden tract, 8 N., 19 W., sec. 17, N. E., N. E.	38.55	18.42	0.262	0.054	None	"
5	Barton tract, 8 N., 19 W......................	17.56	63.64	0.312	0.178	Trace	"
	LOGAN COUNTY.						
6	Freeman's Gap, near Paris....................	19.76	36.32	0.241	0.187	None	Menke.
	SEBASTIAN COUNTY.						
7	Wildcat Mountain, near Fort Smith...........	17.81	10.84	0.414	0.411	A little	Menke.
	SCOTT COUNTY.						
8	"Near Mansfield," 4 N., 30 W., sec. 6........	14.15	51.50	0.286	0.049	None	Menke.
	CRAWFORD COUNTY.						
9	Shay tract, near Lancaster	17.08	40.30	0.274	0.260	A little	Menke.
10	Near Chester	15.87	42.54	0.184	0.054	" "	"
11	Basham tract, near Chester....................	28.30	37.22	0.252	0.128	" "	"

THE MODE OF OCCURRENCE OF THE ORES.

The brown hematites of the Arkansas Valley occur in a number of ways. Sometimes, though rarely, they represent lenticular deposits interstratified with brown sandstones and from a few inches to three or more feet in thickness; elsewhere they occur simply as a network of thin seams from a fraction of an inch to over an inch in thickness, cutting the sandstone in all directions; in still other places, what are locally known as iron ores, are simply sandstones cemented by ferruginous matter. In many places also the ores occur as

local deposits around the mouths of springs. The iron in this kind of ore has been derived from ferruginous rocks by the dissolving action of acidulated surface waters. Rain water falling on the surface of the ground takes up carbonic and other organic acids from decaying vegetation. The water then sinks into the ground, and, by the agency of the acids held in solution, the iron is dissolved out of the rocks. When the water rises again to the surface in the form of springs, the iron compounds in solution become oxidized, and a hydrous sesquioxide of iron is deposited, which, with the exception of an excess of water, is of the same composition as the ordinary brown hematite, and which eventually becomes hardened into that ore. Such deposits are necessarily of only limited extent, rarely covering more than a few acres at the most. They are generally not more than from one to five or six feet in thickness, and usually contain a considerable quantity of sand and numerous fragments of rock, all of which add to the impurity of the ore. Sometimes no springs occur at such deposits, but in these cases it can generally be shown that springs once existed and have become extinct. Sometimes a series of spring deposits occurs along the side of a hill or ridge, following a certain line and forming a broken band, as it were, along the slope. These occurrences are due to the fact that certain positions and materials in the series of rocks underlying the region are more conducive to the formation of springs than others, and the ore deposits, depending as they do on the presence of springs, follow the outcrops of the rocks from which the springs issue. The ideal section in figure 2 illustrates the mode of occurrence of the spring deposits of iron ore.

The spathic or carbonate ore, also known as clay-ironstone, occurs usually in the Carboniferous shales and forms thin layers or a series of lens-shaped masses following certain lines of stratification. The deposits are very small; the layers of ore vary from less than one inch to rarely ten inches in thickness, and the lens-shaped masses have about the same thickness and range from two to over twelve inches in diameter. The

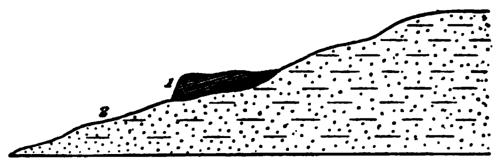

Figure 2. *Ideal section showing the mode of occurrence of iron ore deposited from springs.*
1. Iron ore.
2. Sandstone.

ore, as exposed on the surface, is usually coated on the outside with a red or brown crust from a sixteenth to a half of an inch in thickness; while inside it is of a drab gray color. The outside crust is due to the conversion of the carbonate of iron by oxidation to the sesquioxide of iron.

THE COMMERCIAL VALUE OF THE DEPOSITS.

From the above discussion as to the quality, quantity and mode of occurrence of the iron deposits of the Arkansas Valley, it is evident that, so far as yet discovered, the ores are too low in iron, too high in injurious impurities and occur in too small quantities to permit them to be of any commercial value as a source of iron.

Below are given descriptions of a number of the individual iron ore deposits in this region.

VAN BUREN* AND CONWAY COUNTIES.

General features.—The iron ores of Van Buren county are mostly in the neighborhood of Clinton, Choctaw, Bee Branch and other places in the central and southern parts of the county. They are all either ferruginous sandstones of no commercial value as sources of iron, or else carbonate ores of too low a grade and too limited in quantity to be used. Similar deposits occur in many parts of Conway county.

Choctaw.—The settlement of Choctaw is on Choctaw Creek,

*Only a part of Van Buren county is in the drainage area of the Arkansas River, the rest being on the waters of the Little Red River, a tributary of the White River, but for the sake of convenience in description the whole county is included with the Arkansas Valley counties, especially as the iron ores in it are the same as in those counties.

about six miles southeast of Clinton. Choctaw Creek is a small stream flowing east into the Little Red River. The divide between the two streams is composed of a long ridge capped with sandstone. This rock is often deeply stained with iron and frequently small bunches and layers of brown hematite, an inch or more in thickness, occur through it. These deposits are too poor in quality and the quantity is too small to be of any value. The rusty sandstone is often mistaken for iron ore, and leads to a false impression as to the quantity of the latter. Such materials occur in many places on the divide between Little Red River and Choctaw Creek, especially on the farm of Mr. McGruder, one mile north of Choctaw.

The following analysis by A. E. Menke shows the composition of the ore from the McGruder farm:

Analysis of iron ore from the McGruder tract, Van Buren county.

Iron	24.40
Silica	40 44
Phosphorus	0.276
Sulphur	0 178
Manganese	a little

The analysis shows the ore to be too low in iron and too high in silica to be of any commercial value.

Similar deposits are to be found in many places in Van Buren county south of Choctaw, especially in the neighborhood of Bee Branch and Damascus, and in Conway county near Springfield, as well as at other places, but none of them, so far as yet discovered, are of value.

Lick Mountain.—Lick Mountain is a high hill about six miles south of Clinton and on the north side of Choctaw Creek. On the south side of the hill numerous flat lenticular masses of carbonate or spathic iron ore occur, and are scattered over the slope for a vertical height of about 60 feet, or for a distance up and down the slope of about a hundred yards. The iron ore masses are from 1 to 12 inches in diameter and from 1 to 3 inches in thickness. They are generally coated with a brown crust on the outside, due to the oxidation of the ore, while inside, the drab color of the spathic ore is preserved.

By weathering, the ore masses have been freed from a dark gray shale in which they were originally imbedded, though others can often be seen still in place in the shale. They are too few in quantity and too poor in quality to be of any value.

The following analysis by A. E. Menke shows the composition of the Lick Mountain ore:

Analysis of iron ore from Lick Mountain, Van Buren county.

Iron	20.98
Silica	18.78
Phosphorus	0.524
Sulphur	0.123
Manganese	a little

The analysis shows that the ore contains too little iron to be of any value, while the percentages of silica and phosphorus are also high compared with the amount of iron.

POPE COUNTY.

General features.—The iron ores of Pope county are mostly in the region between the Arkansas River on the south and Illinois Creek on the north and west, in the southern part of the county. They are usually either local deposits laid down by the waters from ferruginous (chalybeate) springs, or they are simply rusty sandstones. All the ores of this region, so far as yet discovered, are of such poor quality, aside from the fact that they are in very small quantities, that they are of no commercial value.

The Guest tract.—The Guest tract is about two miles south of Russellville, on the top of a ridge rising probably 300 feet or more above the surrounding drainage. The ridge is capped with a ferruginous sandstone, and the ore deposit is at the mouth of a spring issuing from this rock. The deposit is probably between one and two feet in thickness, and can be traced for a distance of 40 feet, in a semicircle around the spring. The ore is a loose, porous, brown hematite, containing large quantities of sand and fragments of sandstone. It is simply a small local deposit formed from the waters of the spring. A similar deposit occurs in the bed of a small creek

a few yards distant, and still others occur elsewhere along the ridge.

The following analysis by A. E. Menke shows the composition of the ore on this property:

Analysis of iron ore from the Guest tract, Pope county.

Iron	24.40
Silica	46.86
Phosphorus	0.242
Sulphur	0.164
Manganese	trace

The analysis shows the ore to contain too little iron and too much silica to be of any value; the quantity of the ore is also insignificant as a source of iron.

The Allen Bowden tract.—The Bowden tract is in 8 N., 19 W., section 17, the northeast quarter of the northeast quarter, about eight miles northeast of Russellville. A deposit, similar to that just described on the Guest tract, but about four feet thick, occurs here around the mouth of a chalybeate spring. The rock of the ridge on which the deposit is found is a brown ferruginous sandstone, and the ore crops out around the spring over about half an acre of ground. Possibly, if the deposit were stripped, it might be found to cover a larger area, but at most it is of only limited extent. The ore contains sand and fragments of sandstone.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the Allen Bowden tract, Pope county.

Iron	38.55
Silica	18.42
Phosphorus	0.262
Sulphur	0.054
Manganese	none

The analysis shows the ore to be too low in iron and too high in silica to be of any value. Fragments of a similar material occur elsewhere on the property.

The Dan Barton tract.—The Dan Barton tract is about 300 yards northeast of the Bowden tract just described. The same kind of deposit occurs here as on the last mentioned property,

except that the ore is in even smaller quantities and contains more sand and rock fragments.

The following analysis by A. E. Menke shows the composition of this ore.

Analysis of iron ore from the Dan Barton tract, Pope county.

Iron	17.56
Silica	63.64
Phosphorus	0.312
Sulphur	0.178
Manganese	trace

The analysis shows the ore to contain so little iron and so much silica that it is absolutely worthless.

YELL AND JOHNSON COUNTIES.

General features.—Deposits of iron ore similar to those already described in Van Buren and Pope counties also occur in many places in Yell and Johnson counties, but, as they are entirely valueless as sources of iron on account of the poor quality and the limited quantity of the ore, they do not require further mention. This is true of the deposits in the vicinity of Clarksville in Johnson county.

LOGAN COUNTY.

General features.—Deposits of iron ore similar to those described in the last four counties mentioned occur in many parts of Logan county. None have been found that are of any value. The best known of them is at Freeman's Gap.

Freeman's Gap.—Freeman's Gap is about three miles east-by-south from the town of Paris and is simply a low place in a long ridge running in a general east and west direction. The ridge is composed largely of a brown and often very rusty sandstone. Near the summit of the ridge is a deposit of light, porous, brown hematite, frequently containing many angular fragments of sandstone. An open cut, about 20 feet long and 3 feet wide, has been made in the deposit, and shows the ore to be about three feet in the thickest part and to decrease from this to less than one foot. Below the ore is a deposit of angular fragments of sandstone buried in

sand, which forms the bottom of the pit and probably rests directly on the massive sandstone of the ridge. The ore deposit dips with the slope of the hill at an angle of about 10°, and represents simply a local deposit formed from the waters of a chalybeate spring. Such a spring even now issues from the pit made in the ore and deposits a slimy ferruginous sediment along the course of its waters. The ore is in too small quantities to be of value even if the quality were good.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from Freeman's Gap, Logan county.

Iron	19.76
Silica	36.82
Phosphorus	0.241
Sulphur	0.137
Manganese	none

The analysis shows the ore to be too low in iron and too high in silica to be of any value.

Ores similar to that at Freeman's Gap are said to occur in other places along the ridge, in both directions from the Gap, but they require no further mention.

Paris.—In the streets of the town of Paris the gravel has in many places become cemented by iron, forming a pebbly hardpan often stained black with manganese, and locally mistaken for iron or manganese ore. It is needless to say that it is entirely worthless as an ore of either iron or manganese, as it contains too little of those substances and too much impurity to ever be of value.

FRANKLIN COUNTY.

General features.—The iron ores of Franklin county are similar to those already mentioned in the counties described. They occur in various parts of the county, but have attracted most attention near the town of Ozark, on the Arkansas River. None of the deposits as yet discovered are good enough in quality or contain enough ore to be of any value.

Ozark.—About a mile and a half northeast of Ozark a num-

ber of small deposits of poor iron ore occur along the slope of a sandstone ridge. They represent local deposits laid down by chalybeate springs like those already described in Pope and other counties. The ore is a loose, sandy, brown hematite, containing numerous fragments of sandstone. It is of too low a grade and occurs in too small quantities to be of any value. Similar deposits occur in many other places near Ozark.

The A. W. Poole tract.—The Poole tract is in 9 N., 27 W., section 4, four miles west by a little south from Ozark. On the top of a high sandstone ridge, rising probably between 300 and 400 feet above the surrounding drainage, a few small fragments of brown hematite, from one to three inches in diameter, are scattered through the sandy soil over an area of three or four acres. The ore occurs in Mr. Poole's orchard. The masses of ore have probably been derived from the sandstone and are in very small quantities.

SEBASTIAN COUNTY.

General features.—Iron ores of both the brown hematite and the carbonate or spathic varieties occur in many places in the Carboniferous sandstones and shales of Sebastian county. They are similar to the ores already described in the other counties of the Arkansas Valley, and, so far as known, are in too small quantities and of too poor quality to be of any commercial value. Below are given descriptions of the best known localities.

Wildcat Mountain.—In 8 N., 32 W., section 24, the southeast quarter, four miles southeast of Fort Smith, on the old Waldron and Hayman's Ferry road, and on the west end of a ridge known as Wildcat Mountain, a very small deposit of carbonate ore occurs It varies from two to four inches in thickness, and is an interbedded stratum in a dark gray shale. The rocks are almost horizontal and the outcrop of the ore forms a band along the face of the hill. It is continuous for about 300 feet, and is said to be traceable at intervals for a mile. The ore is reddish brown from oxidation on the outside, but inside it is of a drab gray color and very hard.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from Wildcat Mountain, Sebastian county.

Iron	17.81
Silica	10.84
Phosphorus	0.414
Sulphur	0.411
Manganese	a little

The analysis shows the ore to contain too little iron to be of any value; the quantity of the ore is also very small. Similar ores occur in several other places on Wildcat Mountain.

Hanna Hill.—Hanna Hill is about five miles south-by-east from Fort Smith. On its slope a carbonate ore, similar to that just described on Wildcat Mountain, occurs in a similar shale. The ore varies from one to three inches in thickness, and it is possible that more than one such seam might be found. As on Wildcat Mountain, so here, the ore is in too small quantities and too poor in quality to be of any value.

Massard Prairie.—An ore similar to that at the two last mentioned localities crops out in several places in 7 N., 32 W., section 2, in the bluffs of Little Massard Creek, on Massard Prairie. The ore is imbedded in a gray shale, and varies from one to three inches in thickness. The shale directly overlies the coal bed of this district. What has already been said of the character of the ore on Wildcat Mountain and Hanna Hill applies also to the ore of Massard Prairie.

SCOTT COUNTY.

General features.—The iron ores of Scott county are much like those already described in Van Buren, Pope and other counties. They are mostly either deposits of impure brown hematite around springs, or simply ferruginous sandstones, both equally valueless as iron ores. They occur in many places throughout the county.

"*Near Mansfield.*"—The town of Mansfield is in the southern part of Sebastian county near the Scott county line. A short distance across the line, in 4 N., 30 W., section 6, two miles southeast of Mansfield, is a chalybeate spring sur-

rounded by a deposit of light, porous, brown hematite like that already described in Pope, Franklin and other counties. The ore frequently contains considerable quantities of sand and fragments of sandstone. The deposit covers about an acre on the slope of a ridge and lies on the edges of a massive sandstone. A pit, now partly filled up, has been sunk in the deposit and is said to have passed through ore six feet thick. At present four feet of ore can be seen in the unfilled part of the pit. The deposit is a local one formed from the ferruginous waters of the spring. The ore is too poor in quality and too limited in quantity to be of any value.

Lumps of a similar ore are often plowed up in cultivating a field in the valley at the foot of the ridge on which the above mentioned deposit is situated.

The following analysis by A. E. Menke shows the composition of the ore from the spring:

Analysis of iron ore from "near Mansfield," Scott county

Iron	14 15
Silica	51.50
Phosphorus	0.286
Sulphur	0.049
Manganese	none

The analysis shows the ore to be too low in iron and too high in silica to be of any commercial value.

Eagle Gap.—Eagle Gap is in the extreme southern part of Scott county. It is a pass in the rugged range of sandstone mountains which forms the boundary line between Scott and Polk counties and the divide between the waters of the Arkansas River and those of the Ouachita. A ferruginous sandstone occurs in many places on both sides of the gap, as well as elsewhere in the vicinity, and occasionally small bunches and thin seams of brown hematite are in this rock, but they are in insignificant quantities. The rock, as a whole, though locally called iron ore, is absolutely worthless as an ore on account of its large percentage of silica and its low percentage of iron. Similar materials occur in the mountains both east and west of Eagle Gap.

CRAWFORD COUNTY.

General features.—The iron ores of Crawford county are much like those already described in the other counties of the Arkansas Valley. They are all either sandy brown hematites, or else ferruginous sandstones locally mistaken for ore. They occur in various parts of the county, especially in the valley of Frog Bayou, which passes through the county from northeast to southwest and empties into the Arkansas River.

The Shay tract.—The Shay tract is about two miles northwest of Lancaster, in the drainage area of Frog Bayou, and on the slope of a high sandstone ridge. A dark brown sandstone occurs on many parts of the tract and is usually mistaken for iron ore. It is often hard and flinty, and sometimes occurs in hollow masses, "iron pots," from two to over six inches in diameter. Occasionally also a few small masses of sandy brown hematite occur in the soil.

The following analysis by A. E. Menke shows the composition of the sandy material:

Analysis of iron ore from the Shay tract, Crawford county.

Iron	17.08
Silica	40.80
Phosphorus	0 274
Sulphur	0.260
Manganese	a little

The analysis shows the material to contain so little iron and so much silica that it is entirely worthless as an iron ore.

Chester.—About a third of a mile south of Chester a thin layer, from two to three inches in thickness, of a very impure carbonate or spathic iron ore, occurs in a hard black quartzite. The following analysis by A. E. Menke shows its composition:

Analysis of iron ore from near Chester, Crawford county.

Iron	15.37
Silica	42.54
Phosphorus	0.184
Sulphur	0.054
Manganese	a little

The analysis shows the material to contain too little iron and

too much silica to be of any value as an ore, even if large quantities of it were to be found.

The Thomas Basham tract.—The Basham tract is about three miles south-by-east from Chester. Several small pits have been made on the property in deposits of sandy brown hematite and ferruginous sandstones. The best exposure seen was a bed of ore dipping into the hill southward at an angle of about 5°, and varying from one to three feet in thickness. The deposit is exposed for a distance of about 20 feet and is in an earthy brown sandstone. It is probably only a local, interstratified, lenticular bed of ore, as it appears to be replaced by sandstone at both ends of the exposure. The ore is porous and honeycombed, though sometimes hard and glassy. It usually contains greater or less quantities of earthy impurities.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of iron ore from the Basham tract, Crawford county.

Iron	28.30
Silica	37.22
Phosphorus	0.252
Sulphur	0.125
Manganese	a little

The analysis shows that the ore contains too little iron and too much silica to be of any value, though a somewhat better analysis might be gotten from other samples.

Near this exposure is a cut showing seams of brown hematite, from one to ten inches in thickness, filling joint cracks in the shale and earthy sandstone. This ore is doubtless a secondary deposit derived from the iron in the surrounding rocks. A black, earthy, manganiferous ochre occurs in the same cut in a pocket about two and a half feet wide. Both the iron and the ochre in this cut are in too small quantities and too poor in quality to be of value. Several other small pits have been opened in the same vicinity and on the same property. They show a sandstone, often shaly in appearance, cut by thin layers and bunches of an impure brown hematite from less than one inch to three inches in thickness.

CHAPTER V.

THE IRON DEPOSITS OF THE OUACHITA MOUNTAINS.*

(Pulaski county, the northern part of Saline county, Garland, Hot Spring, Clark, Pike, Montgomery and Polk counties.)

THE LOCATION OF THE DEPOSITS.

The name Ouachita Mountains has been given by the State Geologist to a belt of rugged mountainous country running from Polk county and the Indian Territory border on the west, in an easterly direction to Pulaski county, where the rocky country is abruptly cut off by the low Tertiary area of eastern Arkansas. The iron ores of the Ouachita Mountains, as thus defined, include the deposits of Pulaski county, the northern part of Saline county, Garland, Hot Spring, Clark, Pike, Montgomery and Polk counties. This area is about 125 miles long in an east and west direction, and from ten to over thirty miles wide in a north and south direction. It is the same region in which occur the manganese ores of "southwestern Arkansas," already described in Vol. I of the Annual Report of the Survey for 1890.

It is not to be inferred that iron ore occurs everywhere throughout this belt, as the various localities are often separated by many miles of territory in which no ore occurs; but wherever the ore deposits are found they bear, with few exceptions, certain striking relationships in character, modes of occurrence and geologic positions, and are, therefore, most

*The topographic, geologic and structural features of the Ouachita Mountains, in which the iron deposits are situated, have been fully and carefully worked out by Mr. L. S. Griswold, of the Survey, in his investigation of the novaculite series, and are described by him in the Annual Report of the Geological Survey of Arkansas for 1890, Vol. III. The subject will, therefore, be mentioned here only in a general way, and to such an extent as is necessary for the proper comprehension of the occurrence of the iron ores. For further details the reader is referred to the above mentioned report; also to the Annual Report for 1890, Vol. I, by the present writer, which describes the occurrence of the manganese ores of this region.

consistently treated together, as different exposures of the same series of rocks.

The region in which iron occurs in the Ouachita Mountains is a rugged, mountainous area, with its higher elevations reaching from 1500 to probably over 2000 feet above the sea, and from 500 to possibly over 1000 feet above the surrounding drainage. It is the first really mountainous country met going north from the low, flat or rolling pine region of the extreme southern part of the state. On the north it is separated from the valley of the Arkansas River by a parallel range of mountains, rising sometimes several hundred feet higher than those in question, and known in different places by different names, among which are White Oak Mountain, Cedar Mountain, Blue Mountain, Fourche Mountain,* Irons' Fork Mountain, Rich Mountain and others. Between these two series of mountains, throughout the larger part of the region, the Ouachita River occupies an east and west valley, varying from two or three to twelve miles or more in width. The river rises in Indian Territory, a short distance west of the northwestern corner of of Polk county, and keeps a general east course for almost seventy-five miles; though to follow the curves of the river the distance would be much greater. At the western end of Garland county, it turns southeast, cutting directly across the mountains and forming numerous steep-sided ravines. At the old town of Rockport, where it emerges from the mountains, it changes its course to a general southerly direction, and flows thence south and southeast until it empties into the Black River, a tributary of the Red River, in the state of Louisiana.

The intimate association of the Ouachita River with the mountains in which the iron deposits occur, was the cause of their being named the Ouachita Mountains by the State Geologist. Previously no name had been given to the range as a whole, though many local names were employed. Thus in the region of Pulaski county, west of Little Rock, the mountains are

*This name does not refer here to the Fourche Mountain on the outskirts of Little Rock. It is the same name locally applied to a part of the mountains in Perry county and to a part in Polk and Montgomery counties, both of which areas are immediately south of Fourche la Fave, a tributary of the Arkansas River.

locally called the Fletcher Range; near Hot Springs, in Garland county, they are known as the Hot Springs Mountains; in the northern part of Clark and Hot Spring counties they are known as the Trap Mountains; at the head waters of the Little Missouri River they are known as the Little Missouri Mountains; and around the head waters of the Cossatot River they are known as the Cossatot Mountains. Besides these names of groups of mountains, individual names are given in many places to those elevations which form marked features of the region. This is especially true of the country between the head waters of the Little Missouri and the Cossatot Rivers; here Leader, Hannah, Brushy, Raspberry, Tall Peak, Briar Creek, He, Prairie, McKinley, Porter, Sugar Tree, State House, Little Musgrove, Shadow Rock, Buckeye, and numerous other mountains are well known throughout the region by their individual names.

Speaking in a general way, the Ouachita Mountains consist of a series of parallel ridges, running in a direction varying from east-west to northeast-southwest, and to northwest-southeast; but characterized, on the whole, by a general east-west trend. Sometimes eight or ten of these ridges are crossed in a distance of as many miles, and at other times the whole range is represented by less than half that number scattered over a breadth of twice the distance. Whatever the local strike in a given area may be, all the ridges of that area follow general parallel directions, often curving around and joining each other at their extremities, and thus forming a zigzag across the country in a manner directly dependent on the disturbances to which the region has been exposed. The ridges are separated by mountain streams and frequently rise abruptly to a serrated crest only a few feet wide. Viewed from a distance, they form long narrow elevations with undulating summits, rising in isolated peaks, or sloping off in low places, through which mountain trails find passages across the country. Sometimes the ridges run continuously for many miles without any considerable break, but occasionally a stream

cuts its way through and forms steep, rocky gorges as it successively intersects each ridge in its course.

THE GEOLOGIC RELATIONS OF THE DEPOSITS.

The age and nature of the rocks.—The iron deposits of the Ouachita Mountains occur with a series of novaculites, siliceous shales, quartzites and sandstones, though most of the deposits are immediately associated with the novaculite and the siliceous shales. As regards the geologic age of the ore-bearing rocks, all that can at present be said is that they are Lower Silurian. The only fossils that have been found are a few graptolites which were discovered by Mr. L. S. Griswold, Assistant Geologist of the Survey, in certain shales associated with the novaculites. These have been determined by Dr. R. R. Gurley as belonging mostly to the Trenton horizon of the Lower Silurian. As the exact stratigraphic relations of some of the graptolite shales to the novaculite are as yet uncertain, no more definite correlation can at present be made.

To the north of the Ouachita Mountains is a series of sandstones, quartzites and shales, comprising the mountains on the divide between the waters of the Ouachita and the Arkansas Rivers. These rocks are regarded by the State Geologist as being of Lower Carboniferous age, and are bordered on the north by the Coal Measures of the Arkansas Valley. In their eastern part the Ouachita Mountains come into direct contact with the horizontal Cretaceous and Tertiary beds of that region. In their western part they are bounded on the south by a much less rugged, but equally disturbed, area of Paleozoic (probably Lower Carboniferous) sandstones and shales which extend thence south for about twenty miles, until they come in contact with, and disappear under the horizontal Cretaceous and Tertiary strata. The relation of the sandstones and the shales south of the Ouachita Mountains to those to the north, has not yet been thoroughly worked out, but it seems probable, as has been suggested by the State Geologist, that they may represent the same horizons and may form the two sides of a wide anticline, each comprising numerous subordinate

folds; and that the Ouachita Mountains represent older rocks occupying a position in the breach of this great anticline.

The novaculite with which many of the iron and all the manganese deposits are associated, is a siliceous rock reaching a maximum thickness of probably 450 feet, though often it is very much thinner and possibly, in places, thins out altogether. It is composed of almost pure anhydrous silica, and varies from a hard, translucent rock of a white, gray or buff color, having a conchoidal fracture and a porcelain-like appearance, to a soft, porous and granular material of a massive structure and an irregular fracture. This rock is the most prominent feature of the region, and usually forms the crests of the ridges.

Immediately overlying the novaculite, and exposed on the slopes of the ridges, is a series of gray and black siliceous shales* interbedded with more massive strata somewhat resembling in nature the underlying novaculite, but always showing, on closer examination, a more or less shaly structure, and breaking in large flat slabs. These rocks include practically all the iron ore deposits in this region, except those that occur in the novaculite. Frequently the siliceous shales have undergone a partial decomposition and have been converted into a fine siliceous powder. This is, however, only local, and there frequently occur strata of partly disintegrated rock, carrying fragments of the as yet undecomposed parts, and interbedded with unaltered strata. The disintegration is especially marked near the ore deposits. Good measurements of the thickness of the siliceous shales can rarely be made on account of the highly disturbed condition of the rocks, but they probably aggregate, in their maximum development, about 300 feet, though they are often much thinner.

Overlying the shales is a series of gray and brown sandstones, and above these is a great thickness of shales varying from gray and black to yellow and brown. These rocks, though sometimes seen in some of the synclinal troughs, have no connection with the occurrence of the iron ores of

*These shales are included by Mr. Griswold in his novaculite series.

the region, and the reader is referred to the report of Mr. Griswold, already mentioned, for further details.

Below the novaculite bed there is a series of yellow, brown or gray shales, underlain by a series of black and gray shales with sandstone strata and sandy limestones. In the shales of the latter series are found the Silurian graptolites already mentioned.

Disturbances in the rocks.—The Ouachita Mountains, considered as a whole, represent a portion of the southern part of an area of great disturbance, which extends from the valley of the Arkansas River on the north, in a southerly direction until it disappears beneath the undisturbed Cretaceous and Tertiary strata of the southern part of the state.

The detailed structure of the mountains themselves is complicated, but in a general way they represent a series of parallel folds, which have given rise to the general east-west ridges already described. Subsequent erosion, however, has greatly altered the character of the surface features originally given by these disturbances, and the novaculite, being more resistant than the associated strata, has controlled the topography. The rocks were originally tilted at high angles, in many cases vertically, and were sometimes overthrown. Erosion has since attacked them, carried away the more easily disintegrated beds, and exposed the upturned edges of the novaculite on the crests of all the higher ridges, leaving that rock as the most conspicuous and characteristic feature of the country. The result is a series of novaculite ridges bordered on their lower slopes by the associated shale and sandstone strata. Such ridges generally exist in the forms of anticlines and monoclines. The summits of the anticlines are often removed for considerable distances; the folds are also often overturned and show a dip in one direction throughout. In the latter case the normal anticlinal dips are sometimes seen at the bases of the ridges in the deeper river and creek gorges.

The ore-bearing strata appear in the novaculite at or near its contact with the overlying siliceous shale, and also in the shale

itself. As a consequence of the erosion of the latter rock, the ore-bearing strata are generally exposed on the slopes of the ridges, the ore in association with the novaculite being usually on the upper slopes, and that in the shale on the lower slopes. The ore-bearing strata can be traced in these positions across the country, following the course regulated by the structure of each ridge. In some places they are represented by bodies of ore, in others simply by a stain in the rock.

THE NATURE OF THE ORES.

Varieties of ores.—The iron ores of the Ouachita Mountains are, with the exception of the magnetite of Magnet Cove, in the forms of more or less hydrous sesquioxides of iron, and can all be classed under the general heading of brown hematites or of limonites, when the latter term is used in the broad sense of meaning all the hydrous sesquioxides of iron.* The more common forms are:

(1.) Limonite, hard, brown and often highly siliceous. This variety generally occurs in the siliceous shale that overlies the novaculite, though it is also found at the junction of the two rocks. It usually forms irregularly interbedded lenticular strata, and is more plentiful than any of the other varieties. It is generally very impure on account of its large percentage of silica.

(2.) A dark brown, hydrous sesquioxide of iron; porous, honeycombed structure; glittering vitreous to resinous lustre throughout; streak chrome yellow; hardness 4 to 5. It frequently occurs in a mass composed of stalactitic and botryoidal forms, and the cavities and cracks are often lined with a brilliant red ochre. Its most characteristic feature is its lustre, which is sometimes almost glassy or of a pitch-like character. This distinguishes it from all other ores of the region. It is found only in the gray novaculite or at the contact of that rock with the siliceous shale.

*Speaking accurately, limonite means, according to J. D. Dana, a hydrous sesquioxide of iron containing a certain percentage (14.4 per cent) of water, as indicated by the formula $2Fe_2O_3.3H_2O$, but the term is also often used to mean any hydrous sesquioxide of iron. For the sake of convenience, as already stated in the foot-note on page 8, this general application is used here.

The following analysis, made by Prof. W. A. Noyes, of a specimen of this mineral from the Bud Jones claim, No. 3, Montgomery county, 3 S., 24 W., section 29, the north half, shows its composition:

Analysis of iron ore from the Bud Jones claim No. 3, Montgomery county.

Ferric oxide, (Fe_2O_3)	77.91
Manganese peroxide (MnO_2)	none
Manganese protoxide (MnO)	0.89
Alumina (Al_2O_3)	0.50
Water (H_2O)	16.04
Phosphoric acid (P_2O_5)	4.10
Silica (SiO_2)	0.84
Total	99.78
Metallic iron	54 54
Metallic manganese	0.30
Phosphorus	1.79

The hydration of this mineral is almost exactly intermediate between that of true limonite ($2Fe_2O_3.3H_2O$), which contains theoretically 14.4 per cent of water, and xanthosiderite ($Fe_2O_3.2H_2O$) which contains 18.4 per cent water. The water of the mineral in question approaches a little nearer that of true limonite than of xanthosiderite, but the difference is insignificant, while the pitch-like lustre suggests a resemblance to some forms of the latter.

(3.) A black, glossy, hydrous sesquioxide of iron, frequently in reniform and botryoidal masses; streak brown; hardness 3. The surfaces of the masses have a brilliantly iridescent gloss, showing a variety of shades of blue, green, pink and other colors. This ore occurs in the gray novaculite, and is generally associated with manganese ore, though it is sometimes free from it. The water in it generally approaches that of true limonite.

(4.) A mineral somewhat resembling the last in general appearance, but with a submetallic lustre; reddish-brown streak; hardness 4.5. A specimen of this mineral, examined by Dr. R. N. Brackett, the Chemist of the Survey, contained only 5.4 per cent of water, and has been determined by him as turgite ($2 Fe_2O_3.H_2O$), which is a sesquioxide of iron containing theoretically 5.3 per cent of water.

(5.) A black, massive material; compact structure; lustre submetallic; streak reddish brown; hardness 5. It frequently shows an iridescent surface.

The following analysis, made by Prof. W. A. Noyes, of a sample of this mineral from the Bud Jones claim No. 1, Montgomery county, 3 S., 23 W., section 22, the southeast quarter of the northeast quarter, shows its composition:

Analysis of iron ore from the Bud Jones claim No. 1, Montgomery county.

Ferric oxide (Fe_2O_3)	88.56
Manganese peroxide (MnO_2)	none
Manganese protoxide (MnO)	0.05
Alumina (Al_2O_3)	1.40
Water (H_2O)	8.05
Phosphoric acid (P_2O_5)	0.45
Silica (SiO_2)	1.53
Total	100.04
Metallic iron	61.99
Metallic manganese	0.04
Phosphorus	0.20

The hydration of the mineral is intermediate between that of turgite ($2Fe_2O_3.H_2O$) which contains theoretically 5.3 per cent of water, and that of goethite ($Fe_2O_3.H_2O$) which contains theoretically 10.1 per cent, but it approaches nearer the latter. Its features, however, are such as to suggest the possibility of its being a hematite partially altered by hydration on its surface exposure.

(6.) The magnetite or magnetic ore of Magnet Cove is different from any other iron ore in the Ouachita Mountains, and is further treated under the description of Magnet Cove, later in this chapter.

Quality of the ores.—The analyses given above are of especially good samples of ore, far better than the average run of the deposits. They were selected for the purpose of showing the mineralogical nature of the ores; while to show the commercial value of the ores, samples had to be taken which would represent their character as they would be mined in quantities. The accompanying table is made up of analyses of samples selected in this way. Samples Nos. 1-14 inclusive

were collected by the Survey and analyzed by the Survey Chemists; Nos. 15-19 inclusive have been kindly furnished to the Survey by Mr. W. E. Barns, editor of the *Age of Steel*, St. Louis, Mo.

As has been already stated, the ores occur mostly in two positions in the rocks which comprise the region, one being in the silicious shale, the other at the contact of this shale and the gray novaculite, or, more rarely, entirely within the novaculite bed. The ores in the siliceous shale all belong to the first variety described on page 65, that is they are limonite ores, all commercially classable as brown hematites. They are almost always high in phosphorus and silica, the latter making the percentage of iron low and the ores undesirable, and sometimes of no value whatever. The iron in them varies from 10 to 40 per cent, the silica from 15 to over 60 per cent, the phosphorus from 0.1 to 0.5 per cent. These ores rarely contain more than a very small percentage of manganese.

The ores at the contact of the siliceous shale and the novaculite, or in the novaculite, include varieties 2, 3, 4 and 5, mentioned on pages 65–67. From a commercial standpoint they also may be classed as brown hematites. They are distinguished from the brown hematite just mentioned by the fact that they often, though not always, contain considerable quantities of manganese, forming manganiferous iron ores; in fact, they occur in the same rocks as the manganese ores of this region, and there are all gradations of admixture, from an iron ore with a little manganese to a manganese ore with a little iron. These ores are almost always high in phosphorus and often, though not always, high in silica. The iron varies from less than 10 per cent to over 60 per cent, the silica from 1 per cent to over 75 per cent, and the phosphorus from 0.1 per cent to almost 2.0 per cent.

It will be seen from the accompanying table of analyses that samples Nos. 8, 9, 10, 11, 12, 15, 16 and 19 are good in their contents of iron, or in iron and manganese combined, and in their low percentages of silica, though several of them are in-

jured by their high percentages of phosphorus (see pages 8 to 10); while samples Nos. 1, 2, 3, 4, 6, 7, 13 and 14 contain too little iron and too much silica to be of value.

Analyses of iron ores from the Ouachita Mountains.

Number.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyzed by.
	PULASKI COUNTY.						
1	Capitol Land & Mining Co. tract, 1 N., 14 W., Sec. 24, N. E.	38.80	44.91	0.160	.....	0.39	Brackett.
2	" " " " 1 N., 14 W., Sec. 24, S. E., N.W.	11.82	68.19	0.270	....	8.08	"
3	Whittemore & Bunch tract, 1 N., 14 W., Sec. 14, N. E., S.W.	27.07	46.37	0.470	....	1.62	"
4	R. W. Worthen tract, 1 N., 13 W., Sec 19, S. W., S. W	6.10	75.02	0.184	0.137	None	Menke.
5	" " " 1 N., 14 W., Sec. 24, N. E., S. W	58.42	22.48	0.500	.....	Trace	Brackett.
	SALINE COUNTY.						
6	Iron Mountain, 2 N , 16 W., Sec. 18, S. E..................	35.74	42.79	0.140	.....	A little	"
7	" " 2 N , 16 W., Sec. 18, S. E	11.34	50.60	0.276	0.082	None	Menke.
	GARLAND COUNTY.						
8	Rector & Roulston claim, No. 1, 4 S., 19 W., Sec. 3, S. E...	57.54	2.96	0.670	.....	None	Noyes.
	HOT SPRING COUNTY.						
9	Conley Sullivan claim, 4 S., 20 W., Sec. 26, N. W., S. E....	14.15	1.29	0.560	....	41.54	"
10	Magnet Cove, 3 S., 17 W., Sec. 20, S. W	68.58	5.86	0.028	0.191	A little	Menke.
	MONTGOMERY COUNTY.						
11	Bud Jones claim, No. 1, 3 S., 23 W., Sec. 22, S. E., N. E ...	61.99	1.58	0.200	.....	0.44	Noyes.
12	" " No. 3, 3 S., 23 W., Sec. 29, N. ½	54.54	0.84	1.790	.....	0.30	"
	POLK COUNTY.						
13	J. Guy Lewis claim, 4 S., 28 W............................	16.22	19.32	0.778	0.137	Trace	Menke.
14	Pointed Rock tunnel, 4 S., 28 W., Sec. 19..................	14.51	41.40	0.191	0.082	A little	"
15	Arkansas Development Co. claims...	25.53	0.80	0.767	.....	40.51	St. L. S. & T. W'ks
16	" " " "	35.39	1.88	0.230	....	27.68	"
17	" " " "	16.83	29.00	0.343	....	26.20	"
18	" " " "	22.26	44.40	0.576	....	11.93	"
19	" " " "	50.38	...	1.450	.....	2.06	"

THE MODE OF OCCURRENCE OF THE ORES.

As already stated, the iron ores of the Ouachita Mountains occur in two positions in the rocks of the region: one in the siliceous shale, the other between this shale and the novaculite, or in the novaculite. The manganese ores of the Ouachita Mountains also occur between the shale and the novaculite or in the novaculite; in fact, many of the iron claims were taken up under the impression that the ore was manganese.

The iron ores in the siliceous shale are more abundant than those in the other positions, and occur usually as lenticular bodies following in a general way the lines of stratification of the rocks. Sometimes, however, they occur as nests, and as short disconnected seams, ranging from a fraction of an inch to a foot or more in thickness, and cutting the rock in all directions, though confined to a certain stratigraphic position in the series of rocks. The larger and more regular bodies of ore vary from two or three to ten feet or more in thickness. Sometimes they are traceable along their outcrop for a hundred yards or more, at other times for only a few feet. Occasionally such lenticular bodies occur at intervals for a distance of several miles following one certain position in the rocks. Sometimes several seams of ore run parallel to each other at a distance apart of from a few inches to several feet, separated by similar strata of siliceous shale. The latter have frequently been much decomposed, and are often in the form of a fine powder containing harder masses of as yet undecayed shale. This decay, however, is only local, and frequently a decomposed stratum several inches in thickness is bordered on both sides by unaltered strata of the same rock. The iron ore blends into the country rock along the same stratum, and the continuance of any one lead of ore is very uncertain. When it thins out, however, it generally appears again in the same relative position at a greater or less distance beyond, while the intermediate barren rock is usually stained with iron in the direction of the strike of the deposit.

The iron ores at the contact of the siliceous shale with the

novaculite, or in the novaculite, are in smaller quantities than those in the shale. They occur either as thin beds following lines of stratification and from a few inches to two or three feet in thickness, or as a mass of small nests, pockets and short disconnected seams, from a fraction of an inch to a foot or more in thickness, intersecting the rock in all directions; or, as is often the case, the iron ore forms the cement of a brecciated novaculite, in which the masses of rock vary from a fraction of an inch to several inches in thickness. The part of the rock thus impregnated, in other words the breccia, varies from two or three feet to fifty feet and more in width. The ore, however, forms only a small proportion of the mass, in some places nor more than 1 per cent, while in others, especially where the ore-bearing stratum is thin, it forms a larger percentage.

The iron ores in the novaculite or at its contact with the shale, are in many places intimately mixed with manganese ores, forming manganiferous iron ores or ferruginous manganese ores; in other places the two ores occur in the same pocket, but in separate masses; and in still others, they occur in different places along the same ore-bearing stratum. On He Mountain, Polk county, there are geodes of brown hematite lined with black manganese ore; and a frequent occurrence elsewhere is a kernel of brown hematite coated with manganese, either as a hard incrustation of massive ore, or as radiating, fibrous crystals of pyrolusite. Stalactitic ore with brown hematite inside and manganese ore outside sometimes occurs. The outcrops of the ore-bearing rocks at the contact of the novaculite with the shale, and in the novaculite, can be traced in the same way as those already described in the shale.

The iron ores in both the novaculite and the shale usually show a tendency to follow lines of bedding, but sometimes they occur in crevices across the bedding, forming deposits as much as two or three feet in thickness. These seem to have been formed by the collection of the ore in such positions by a process of solution and redeposition of the ore from deposits originally bedded. Such a case is described later in this chap-

ter in the Bud Jones claim No. 3, 3 S., 23 W., section 29, Montgomery county.

As has already been stated, the whole region of the Ouachita Mountains has been thrown into a series of parallel folds, striking from east-west to various angles to that direction. The novaculite, by reason of its superior power to resist erosion, forms the predominating rock in these ridges, usually occupying the crests. The siliceous shale, which geologically belongs above the novaculite, has been worn down and occupies the lower slopes of the ridges. As a result of this structure, the ore in the novaculite, or at its contact with the shale, usually occurs on or near the tops of the ridges, though sometimes, where there has been excessive erosion, it is found lower down; while the ore in the shale almost always occupies the lower positions and generally occurs in, or on the sides of, the synclinal valleys separating the ridges. The ore belts in both rocks follow the same general direction, and have steep and often perpendicular dips.*

The section given in figure 3 shows a typical case of the mode of occurrence of the iron ore in the siliceous shale and also at the contact of that rock with the novaculite. The deposits marked C represent the ore in the shale; that marked D is the ore at the contact. The continuation of the ore below the surface, as represented in the figure, is imaginary, as no mining has been done, but it shows the general direction of the downward extension of the deposits and also their parallelism. The thickness of the ore beds as represented in the figure is greatly exaggerated, this being necessary in order to make the position of the deposits clear. The property from which this section was obtained is more fully described later in this chapter.

THE COMMERCIAL VALUE OF THE DEPOSITS.

From the facts given in the above discussion of the nature and the modes of occurrence of the iron ores of the Ouachita

*The structure of the ore deposits is more fully treated in the Annual Report of the Geological Survey of Arkansas for 1890, Vol. I, in the discussion of the manganese deposits of southwestern Arkansas.

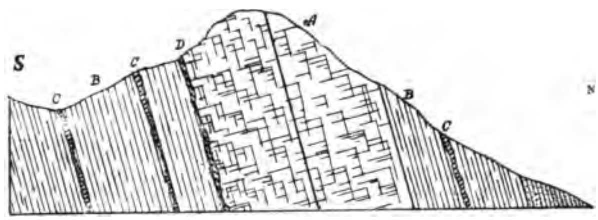

Figure 3. *North-south section through the Bud Jones claim No. 1, Montgomery county, showing the occurrence of the iron deposits.*

A. Gray novaculite.

B. Siliceous shale.

C. Iron deposits in the siliceous shale.

D. Iron deposit at the contact of the siliceous shale and the novaculite.

Horizontal scale: 1 inch = 800 yards. Vertical scale: 1 inch = 400 feet.

Mountains, the following conclusions have been reached: the only ores which have as yet been found in more than very limited quantities are those in the siliceous shale; but these are usually too low in iron and too high in silica to be of any value, and, where the quality is above the average, the quantity of the ore is generally too small to permit profitable mining. The deposits in the novaculite and at its contact with the shale are very small, and even if larger deposits were found, the analyses show that the ores in these positions almost invariably contain too much phosphorus to command a high price. Moreover, the ores in all the positions are associated with hard rocks and often dip vertically, or almost so, making them expensive to mine. The nearest railways are from seven to, more generally, over twenty miles distant. Limestone is scarce and usually altogether absent in the vicinity of the ores, and there is no coal nearer than the Arkansas Valley, with which region the ore deposits of the Ouachita Mountains have no direct railway connection. There is, however, a large amount of timber, and with cheap charcoal fuel and improved transportation facilities, there is at least a possibility of the future utilization of a few of the better ores. The industry, however, would never be an important one, and could only be carried on under the most favorable conditions of transportation and markets, conditions which at present are far from being realized.

PULASKI COUNTY.

General features.—The iron ores of Pulaski county are mostly west and south of Little Rock, in the western part of the county. A large amount of the prospecting that has been done, has been carried on in the drainage area of Fourche Bayou, a tributary of the Arkansas River, and especially in the neighborhood of McHenry Creek, a small branch of the Fourche. A part of this region is known as the Fletcher Range. The ores are either brown hematites in place in the novaculite and siliceous shales of the hills, or impure bog iron ores in the creek beds. Both ores are in the same region as the manganese ores of Pulaski county, already described in the Annual Report of the Survey for 1890, Vol. I, pages 327–335; and the iron and manganese ores frequently occur together in the same deposits. The iron ores, like the manganese ores, are either in too small quantities or of too poor quality to be of value.

The Capitol Land and Mining Company.—The Capitol Land and Mining Company commenced operations on the manganese and iron deposits in the Fletcher Range in the spring of 1888. Several small pits and tunnels were made, and the site of the town of Martindale was laid out in 1 N., 14 W., section 14, the northeast quarter. No ore was shipped and operations were suspended after a few months.

The company controls the following tracts of land, all of which are situated in 1 N., 14 W.: Section 12, the southwest quarter of the southwest quarter; section 11, the south half of the southeast quarter, and the whole of the southwest quarter; section 10, the southwest quarter; the whole of section 14, except the east half of the northwest quarter, and the northeast quarter of the southwest quarter; section 15, the northeast quarter and the northwest quarter, with the exception of the southwest quarter of the latter; section 23, the northeast quarter with the exception of the southwest quarter of it; section 24, the north half.

This property is situated in the basin of McHenry Creek, which runs diagonally from northwest to southeast through

1 N., 14 W. The stream is bordered on either side by the novaculite and the siliceous shale, already described, which form rocky ledges rising from one to probably two hundred feet above the creek. In some places the hills encroach on the stream and form narrow gorges; in others they widen out for a few hundred yards and give room for small areas of open land. The property of the Capitol Land and Mining Company includes a part of both the creek bottom and the hills on either side. Bog iron and manganese ores exist in many places along the creek, while in the hills small quantities of brown hematite and manganese ore occur in place in the rock.

(1.) The Bog ores.—The bog ores occur in association with a greater or less quantity of clay, and angular or rounded fragments of novaculite and shale from a fraction of an inch to several inches in diameter. They often form the cement of a breccia or conglomerate of these fragments. The ores are generally earthy and soft, though in places they are more compact, and are sometimes in the form of kidney-shaped and stalactitic masses. The iron and manganese in them are intimately associated, and the color of the ores varies from brown to black, according as the iron or manganese predominates. There are all stages of admixture, from a bog iron ore with little or no manganese to a bog manganese ore with little or no iron. Frequently numerous ferruginous, or chalybeate, springs rise from the ore beds and deposit about their orifices a brown sediment of hydrous sesquioxide of iron.

The thickness of the bog deposits varies from a few inches to probably ten feet. Where pits have passed through them, they are usually found to be underlain by gray clay containing fragments of rock similar to those associated with the ore. The bog ore protrudes into and recedes from the underlying bed in a very irregular manner, in some places running down into it for several feet, in others thinning out and allowing it to appear on the surface. The ore deposits represent simply beds of clay and gravel derived from the erosion of the surrounding hills, and impregnated with iron and manganese from springs, and pos-

sibly also from surface waters draining off the surrounding hills.

These deposits in some places occur in the bed of the creek, in others in the low banks on either side, and they also often crop out in the bottoms of the ravines that open upon the creek from the hills. The deposits have been traced at intervals from near the mouth of McHenry Creek to six miles above, but most of them occur along that portion of the creek extending from the central part of section 24 in a northwest direction to the western part of section 14, a distance of about a mile and a half. Above and below this area the clay of the creek bed is occasionally discolored by manganese and iron, but it does not contain any considerable quantities of those materials.

The iron ore is in quantities too small and of too poor quality to be of any value. The following analyses show the composition of the bog ores. All the samples analyzed are from the property of the Capitol Land and Mining Company, with the exception of No. 2 which is from the Whittemore and Bunch tract, described later in this chapter:

Analyses of bog iron and manganese ores from McHenry Creek, Pulaski county.

No.	LOCALITY.	Iron.	Silica.	Phosphorus.	Manganese.
1	I N., 14 W., sec. 24, N. E.	33.80	44.91	0.160	0.39
2	1 N., 14 W., sec. 14, N. E., S. W..	27.07	46.87	0.470	1.62
3	1 N., 14 W., sec. 24, S. E., N. W ..	11.82	63.19	0.270	8.08
4	1 N., 14 W., sec. 24, S. E., N. W ..	2.88	42.83	0.116	27.34
5	1 N, 14 W., sec. 24, S. E., N. W ..	3.09	4.83	0.001	59.68

The samples for the above analyses were selected so as to show the transition from a bog iron ore to a bog manganese ore. In each sample the larger fragments of rock were removed, and the impurities that remained were such as would be retained in the ore if it were crushed and washed.

Sample No. 5 is from a small stripping on the south bank of

McHenry Creek. It represents a picked sample of the very best manganese ore that could be found on the creek. Only very small quantities of such ore occur and the amount is of no commercial importance. The other analyses are of average samples and show that the ores are too high in silica, and too low in iron and manganese, to be of any value.

(2.) The ores in the hills.—In the hills, both north and south of McHenry Creek, numerous small openings have been made, and some of them show iron and manganese ores in place in the rock. On the summit of the ridge that runs along the south side of the creek from 1 N., 14 W., section 24, the northwest quarter, to section 15 the northwest quarter, several cross cuts have been made in the novaculite. They sometimes show small quantities of iron and manganese ores, but usually not more than a stain. In section 24, the southwest quarter of the northwest quarter, a shaft has been sunk on rock impregnated in this manner. The shaft is now nearly filled with water, but it is said to be about 25 feet deep. In section 24, the northwest quarter of the northwest quarter, a drift was run for about 50 feet into the siliceous shale, in the bluffs on the south side of McHenry Creek. No ore was found.

A few cuts have also been made in the ridge on the north side of the creek, extending from 1 N., 14 W., section 13, the east half, to section 11, the southwest quarter, and passing north of the site of Martindale. The ore occurs in this ridge in a manner similar to that of the ores just described. A short distance north of Martindale, a cut, about fifty feet long and five feet wide, has been made in the siliceous shale, which has partly decomposed into a hard clay. The cut has exposed small quantities of brown hematite, in pockets and in disconnected layers, from one to five feet in length, and from one to five inches in thickness.

The Whittemore and Bunch tracts.—Messrs. Whittemore and Bunch own several tracts of land and several manganese and iron ore claims in the western part of Pulaski county. Among

the openings that have been made on the iron claims are those described below.

(1.) 1 N., 14 W., section 14, the northeast quarter of the southwest quarter, and the southeast quarter of the northwest quarter.—This property is on the banks of McHenry Creek. A small prospecting pit has been sunk in a deposit of impure bog iron ore, but no considerable work has been done. The ore is of a rusty brown color and contains numerous fragments of rock and inclusions of clay. Further details about this class of ore are given on pages 75-77.

The following analysis by Dr. R. N. Brackett shows the composition of the ore from this tract:

Analysis of iron ore from the Whittemore and Bunch tract.

Iron	27.07
Silica	46.87
Phosphorus	0.47
Manganese	1.62

The analysis shows the ore to contain too little iron and too much silica to be of any value; moreover, it is in too small quantities to be worked, even if the quality were good.

(2.) 1 N., 13 W., section 19, the north half.—Messrs. Whittemore and Bunch have prospected a claim in this locality, and a small cut about twenty feet long and six feet wide has been made in the siliceous shale. The rock has a rusty stain and occasionally contains lenticular layers of iron ore, from one to three inches in thickness. The ore is in such small quantities as to be of no commercial importance.

The R. W. Worthen tracts.—Mr. R. W. Worthen owns several tracts of land containing manganese and iron deposits in 1 N., 14 W., and 1 N., 13 W. Among the openings that have been made in iron ore are those described below.

(1.) 1 N., 14 W., section 24, the northeast quarter of the southwest quarter.—Two small pits have been sunk on this property in the novaculite on the summit of a hill immediately south of McHenry Creek. They show manganese ore and brown hematite in small irregular seams and pockets, from one to three inches in thickness, scattered through the rock.

Sometimes the two ores are intimately mixed as a manganiferous iron ore; at other times they occupy different places along the courses of the same seams. Neither ore is in workable quantities.

The following analysis by R. N. Brackett shows the composition of a sample of iron ore from this property:

Analysis of iron ore from the R. W. Worthen tract, Pulaski county.

Iron	53.42
Silica	22.48
Phosphorus	0.50
Manganese	trace

The analysis shows the ore to be good in its contents of iron but high in silica and phosphorus.

In the southeast quarter of the southeast quarter of the same section, a shallow pit, about ten feet square, has been made in a gray novaculite, near the top of a hill. The novaculite is cut up with seams and nests of brown hematite, from one to three inches in thickness, forming a network through the rock. These are seen on all sides of the pit, and are traceable elsewhere on the surface of the hill in greater or less quantities. The ore often forms the lining of hollows in the novaculite, and in such cases is frequently coated with a black incrustation. The ore is hard, very siliceous, sometimes contains crystals of quartz, and is too poor in quality and in too small quantities to be of any commercial value.

(2.) 1 N., 13 W., section 19, the southwest quarter of the southwest quarter.—Here the same brown hematite occurs as at the last place, except that the seams are more numerous and frequently form concentric layers around masses of novaculite. The ore-bearing rock forms the crest of a ridge and is bordered on either side by gray siliceous shale. The ore often consists simply of novaculite stained with iron. It is not in sufficient quantities to be of any commercial value, even if the quality were good. The following analysis by A. E. Menke shows its composition:

Analysis of iron ore from the R. W. Worthen tract, Pulaski county.

Iron	6.10
Silica	75.02
Phosphorus	0.184
Sulphur	0.137
Manganese	none

The analysis shows the material to contain too little iron and too much silica to be of value.

(3.) 1 N., 13 W., section 19, the northwest quarter of the southwest quarter.—Here a small pit has been made on a hard gray novaculite, containing seams of manganese ore and brown hematite, from a fourth of an inch to one inch in thickness, and with nests of the same materials from one to six inches in diameter. Both ores are in very small quantities.

Exposures similar to those described occur in numerous other places on Mr. Worthen's lands in 1 N., 13 W., sections 29 and 32, but do not require further mention. In section 29, the northeast quarter of the southeast quarter, the novaculite along the summit of the ridge is often stained with iron and occasionally with a little manganese, but no commercially important quantities of either ore are seen.

The Robbins tract.—The Robbins tract is in 1 N., 14 W., section 5, the southwest quarter of the northeast quarter. The iron ore occurs in the siliceous shale, in a crevice or fissure running across the strike of the rock. The deposit varies from one to three feet in thickness, averaging probably 20 inches, and dips almost vertically, with a slight inclination to the southeast. It strikes N. 55° E., while the shale strikes at almost right angles to that direction. The ore varies from a hard to a soft brown hematite, the soft variety being sometimes almost black. At the sides of the ore deposit, and between it and the shale, are numerous fragments of that rock, and similar fragments also occur in the ore itself. The deposit probably represents a local fissure filled with ore by the segregation of the minute quantities of iron contained in the surrounding rocks.

The deposit has been stripped along its strike for a distance

of about 75 feet, and possibly extends further. The ore occurs in too small quantities to be of commercial value.

Other localities in Pulaski county.—Deposits of iron ore similar to those already described occur in many other places in the western part of Pulaski county. In 1 N., 14 W., section 30, the southwest quarter of the southeast quarter, there is a stratum of brown hematite from three to four inches in thickness, interbedded with the siliceous shale. It dips at about 33° to the northeast. The ore is hard, laminated, and often shows a mammillary surface. The laminae are frequently coated with a black gloss.

Outcrops similar to that just described occur in many places in section 30, and similar ore is said to be traceable at intervals for over seven miles in a direction of a little north of west. Wherever it has been seen, however, the ore is in too small quantities to be of value.

THE NORTHERN PART OF SALINE COUNTY.

General features.—Most of the iron ore of Saline county is in the low Tertiary region comprising the southern part of the county, but in the northern part, which is in the area of the Ouachita Mountains, iron ore has been found in several places. The ores in this northern part of the county, so far as known, are either of too poor quality or occur in too small quantities to be of any value. The best known of the localities is Iron Mountain.

Iron Mountain.—What is locally known as Iron Mountain is in 2 N., 16 W., section 18, the southeast quarter, about two miles north of Brazils Post-office. The ore is a soft, yellow, ferruginous substance interbedded with layers of hard sandstone. These materials dip at a high angle into the southeastern slope of a hill rising probably over 150 feet above the surrounding drainage. Their outcrop reaches from the base of the hill, where it is obscured by soil and loose rock, up the slope to near the summit, where it is cut off by an overlying bed of massive sandstone. The ore and the associated layers of sandstone are probably together several hundred feet thick. All

the rocks of the hill, including the ore, are cut by veins of quartz often eight or ten feet in thickness.

The ore is light and earthy, often sandy, and contains numerous small rounded masses, from an eighth to a half of an inch in diameter, of a soft, gray, siliceous material. These masses are coated with a thin layer of hard, brown hematite, a sixteenth of an inch or more in thickness, and outside of this is the earthy ore. On the surface, the gray masses weather out, leaving a siliceous skeleton.

There are large quantities of this ore on the property, but, as shown by the following two analyses, the first by A. E. Menke, the second by R. N. Brackett, it is of too low grade to be of value:

Analyses of iron ore from Iron Mountain, Saline county.

Iron	11 34	35 74
Silica	50.60	42 79
Phosphorus	0.276	0.14
Sulphur	0.082	....
Manganese	none	a little

The analyses show that the ore contains too little iron and too much silica to be used as a source of iron.

GARLAND COUNTY.

General features.—Iron ores occurring under conditions somewhat like those already described in Pulaski county are found in several places in Garland county, but no mining has been carried on. A little prospecting has been done and several claims have been taken up, usually under the impression that the ore was manganese. The ore is in very small quantities.

The Rector and Roulston claim No. 1.—The Rector and Roulston claim No. 1 is in the southeast corner of Garland county, in 4 S., 19 W., section 3, the south part of the southeast quarter. It is on a ridge running in an east-west direction and composed in its central part of gray novaculite, bordered on either slope by black or gray siliceous shale. The rocks dip almost vertically. Iron ore in the form of a porous brown hematite is found on the southern slope of this ridge, in

the gray novaculite, at or near its contact with the shale. The ore is not seen in place in the rock, but masses of it from one to two hundred pounds in weight, as well as large slabs of rock carrying masses of ore, are plentiful along the line where the deposit would crop out were it not covered by loose material. Judging from the character and distribution of these masses, the ore in the bed rock probably runs through the novaculite in seams and bunches from one inch to several feet in thickness, and the rock containing this ore probably occupies a belt from twenty-five to thirty feet in width, running in the direction of the ridge and bordered on either side by barren rocks. It is not probable that this iron ore will be found in quantities sufficient to work at a profit.

The following analysis by Prof. W. A. Noyes shows the composition of the ore:

Analysis of iron ore from the Rector aud Roulston claim No. 1, Garland county.

Iron	57.54
Silica	2.96
Phosphorus	0.67
Manganese	none

The analysis shows the ore to be of very good quality in its high percentage of iron and low percentage of silica, but it contains an injurious amount of phosphorus. The sample analyzed contained no manganese, but it is not impossible that small and unimportant quantities of manganese ore may be found in the same deposit elsewhere on the property.

Three hundred yards north of this ridge, is another parallel though somewhat smaller ridge. On both of its slopes, at the line of contact of the gray novaculite which forms the upper part, with the siliceous shale which forms the lower part on both sides, are exposures of iron ore similar to that just described. Small masses of a hard manganese ore occur with the iron ore, but both ores are in very limited quantities.

The Rector and Roulston claim No. 2.—The Rector and Roulston claim No. 2 is in the southeast corner of Garland county, less than half a mile north of the line of Hot Spring

county, in 4 S., 19 W., section 10, the south half. Iron ore occurs here in the same rock and in the same position as at the last locality described. The ore itself, however, differs slightly from the ore at that place. It is of a bright vitreous nature, frequently filled with small cavities. It occurs in thin seams and pockets, from a fraction of an inch to three inches in thickness, honeycombing the gray novaculite for a width of about ten feet, and often giving the rock a brecciated appearance. This ore-bearing part of the novaculite occurs just above the contact of that rock with the siliceous shale, on the north slope of the ridge. The ore is not seen in workable quantities.

HOT SPRING COUNTY.

General features.—Iron ores in association with novaculite and siliceous shale occur in many places in the northern part of Hot Spring county. The nature and the mode of occurrence of these ores are much the same as have already been described in the other counties of the Ouachita Mountains. The iron ores often occur in intimate association with the manganese ores, but no large quantities of either have yet been discovered. Besides the ores in the novaculite and shale, Hot Spring county contains the magnetite, or magnetic ore, of Magnet Cove, which will be more fully described later in this chapter.

The Conley Sullivan claim.—The Conley Sullivan claim is in 4 S., 20 W., section 26, the northwest quarter of the southeast quarter, on the north side of an irregular, rocky hill of gray novaculite. Manganese and iron ores occur together in the rock, and the surface of the hillside is strewn with fragments of both. The iron ore occurs as a brown hematite, often porous and of a vitreous character. The manganese is a porous, black ore, often in stalactitic forms. The ores occur both in separate masses and in an intimate admixture, forming a manganiferous iron ore or a ferruginous manganese iron ore. Sometimes small stalactitic branches are found which are composed of manganese ore on the outside and

iron ore on the inside. In one place there is a solid mass of the mixed ores weighing several hundred pounds, in which manganese largely predominates. Many similar though smaller masses are strewn over the surface, though, on account of the debris, good exposures of the ore in place in the bed rock cannot be seen. Its extent, however, is probably limited.

The following analysis by W. A. Noyes shows the composition of this ore:

Analysis of ferruginous manganese ore from the Conley Sullivan claim, Hot Spring county.

Iron	14.15
Silica	1.29
Phosphorus	0.56
Manganese	41.54

The analysis shows that the percentage of iron and manganese combined is very good, but that the value of the ore as a manganese ore is seriously injured by the high percentage of phosphorus.

The Henry Little claim.—The Henry Little claim is in 4 S., 21 W., section 15, the northwest quarter, and is less than half a mile southeast of Lightfoot Springs. It is in the western part of the Trap Mountains, a range of the Ouachita Mountains which passes east and west through the northern part of Hot Spring county. A few blasts have been made on this property in a novaculite ledge carrying the same porous, stalactitic iron ore as that found at the Conley Sullivan claim, except that there is little or no manganese with the iron. The ore is often coated with a brilliant red ochre. The thickness of the deposit cannot be seen, as it is mostly covered by debris, but some large masses of ore weighing several hundred pounds have been blasted out. What has been already said at regards the quantity of ore at the Conley Sullivan claim may also be applied here.

The same lead of ore as that at Lightfoot Springs is said to be traceable at intervals for four miles east and two miles west of the Springs. Similar though smaller deposits of iron ore are found in many other parts of the Trap Mountains.

Magnet Cove.—The area known as Magnet Cove is in 3 S., 17 and 18 W., in the northern part of Hot Spring county, on the north side of the Ouachita River, and twelve miles east-by-south from the city of Hot Springs. The cove is an elliptical basin composed largely of igneous rocks, and surrounded by ridges of sedimentary rocks. It comprises an area of about a thousand acres. The geology, mineralogy and petrography of this remarkable region have been so well and so fully treated by Dr. J. Francis Williams* that no further details will be given here, except in so far as they relate to the occurrence of the iron ores. For any further facts the reader is referred to the above mentioned report.

The magnetic iron ore of Magnet Cove is in 3 S., 17 W., section 20, the southwest quarter. It occurs in loose fragments, from particles the size of sand grains to masses several inches in diameter, and is scattered over the surface of about five acres, though it is found sparingly outside of this area. It occurs most abundantly immediately on the main Hot Springs road, covering the top of a small, round knoll. The masses of ore in the area of their most abundant occurrence form an almost solid layer on the surface, thinning out in all directions. Below the surface they become fewer. The surface soil is of a dark chocolate-brown color, with innumerable specks and flakes, often two or three inches across, of a pearly white micaceous mineral (protovermiculite). Below the surface, the soil is of a lighter color.

In a washout in the side of the road, masses and irregular seams of ore occur *in situ* in a rock recognized by Dr. Williams as eleolite mica syenite, and composed largely of protovermiculite and a white feldspar. The rock is in a high stage of decay, and crumbles easily, being but little more coherent than the surface soil, though it still shows its original structure. Such occurrences as these lead to the belief that the loose fragments of ore on the surface have been derived from the decay *in situ* of this crystalline rock; and that they originally

*Annual Report of the Geological Survey of Arkansas for 1890, Vol. II, The Igneous Rocks of Arkansas.

occurred in the rock as masses and irregular seams, but that when it decayed, these masses of ore were set free, more or less broken by weathering, and scattered through the present soil, which is also the result of the decay of the same rock. The occurrence of the ore more plentifully on the surface than below, is doubtless due to the fact that on the surface the loose soil is constantly being carried off by the action of the surface waters, while the heavier lumps of ore, being less easily carried, remain behind and are in this way gradually concentrated; but below the surface, where no such erosion can go on, the masses of ore are more scattered. By some it is said that the ore disappears altogether at a depth of a few feet. If this is a fact, it is a result of the nature of the deposit, which probably originally represented a part of the rock containing ore and surrounded above, below and on all sides by rock containing no ore.

The quantity of iron ore at Magnet Cove is too small to be of any commercial value as a source of iron, though there is a limited demand for it as cabinet specimens.

The ore is usually massive, very hard, dull black or rusty on the outside, and bright black on the inside. It frequently shows botryoidal protuberances on the surface. It has a conchoidal fracture and a metallic lustre.* The ore is a magnetite, and its most remarkable feature is that it is sometimes, though not always, highly polarized, forming a loadstone. In fact, the strong magnetism of many specimens is what has given the name to Magnet Cove.

The following analysis by D. D. Owen,† of a picked specimen, shows the composition of the ore from a mineralogical standpoint.

*For a fuller mineralogical description of this magnetite the reader is referred to the report of Dr. Williams, mentioned above.

†Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas, page 105. In quoting the analysis the arrangement has been somewhat changed from the original, and the chemical symbols have been introduced, but the figures are the same.

Analysis of iron ore from Magnet Cove, Hot Spring county.

Peroxide of iron (Fe_2O_3)	67.20
Protoxide of iron (FeO)	24.46
Insoluble matter (SiO_2 etc.)	3.20
Titanic acid (TiO_2)	1.20
Protoxide of manganese (MnO)	0.30
Alumina (Al_2O_3)	0.45
Moisture (H_2O)	1.00
Lime (CaO), magnesia (MgO) and loss	2.19
Total	100.00

The following analysis by A. E. Menke, of an average sample, shows the composition of the ore from a commercial standpoint:

Analysis of iron ore from Magnet Cove, Hot Spring county.

Iron	68.58
Silica	5.86
Phosphorus	0.028
Sulphur	0.191
Titanium	1.159
Manganese	a little

The analysis shows that the ore is high in iron and low in silica and phosphorus, but contains a considerable amount of titanium.

About 14 or 15 years ago, some St. Louis capitalists bought a tract of ten acres which included the iron ore deposit of Magnet Cove. They believed that the ore was in large quantities, and it was their intention to mine it for the manufacture of iron. After they had done a small amount of prospecting, they found that the ore was in too small quantities to mine for this purpose, and they abandoned the project.

CLARK COUNTY.

General features.—The Ouachita Mountains pass through the extreme northern part of Clark county, and occasionally the rocks of that region contain small quantities of manganese and iron ores, but no important deposits of either ore have been found.

Point Cedar.—Small quantities of impure iron ore occur in 5 S., 22 W., four miles west of Point Cedar, in the novaculite ridge that runs in a general direction of a little south of west through the extreme northwestern part of Clark county. The

ore appears in a sag on the summit of the ridge, but it is in quantities too small to be of any value. It is but little more than a stain in the rock.

PIKE COUNTY.

General features.—Iron ores similar to those in Clark, Garland and other counties occur in many places in the novaculite ridges that comprise the extreme northern part of Pike county. The ore is not in sufficient quantities to be of any value.

Rundle's Creek.—Rundle's Creek is a small branch of the South Fork of the Caddo River, running east through the northwest part of 5 S., 25 W., and bordered on either side by novaculite ridges. In section 4, the southeast quarter of the northeast quarter, on the slope of the ridge immediately north of the creek, small quantities of brown hematite occur, together with a little earthy manganese ore. The ores form the cement of a well-developed breccia of novaculite fragments, but compose only a small fraction of the mass. The breccia in some places is from ten to fifteen feet in width, but the ore is very limited in quantity. Similar outcrops occur along the slope of the mountain, in the direction of the strike of the rocks, for a mile, and they are said to be traceable for a still greater distance.

In section 4, the southeast quarter, a short distance south of Rundle's Creek and on a spur of the main mountain, there is iron ore associated with small quantities of manganese ore. The ores occur in small irregular pockets in the gray novaculite. The iron ore is frequently composed of nodules with a radiating structure, and from an eighth of an inch to one inch in diameter. The main ledge is mostly obscured by loose material, but fragments of iron ore from fifty to a hundred pounds in weight occur on the surface. One pocket of ore exposed in place in the rock measured between three and four feet across. The quantity of the ore is too small to be of any value.

Line Mountain.—Line Mountain is a novaculite ridge running east and west approximately on the boundary line of Pike and Montgomery counties, two miles south of Fancy Hill

Post-office. Brown, laminated iron ore and manganese ore are found along the southern slope of the mountain, in Pike county. The main outcrop is obscured by loose material, but small fragments of both the iron and the manganese ores are scattered at intervals along the mountain slope, and similar fragments are said to be found along the mountain for seven miles. The quantity of both the iron and the manganese ore is exceedingly small.

Other localities in Pike county.—In the northern part of 5 S., 27 W., and on the south slope of the most southerly of the novaculite ridges in the northern part of Pike county, is a series of soft earthy sandstones, with interbedded red and gray shales. In many places brown hematite occurs in the sandstone, in one place forming a lenticular bed three feet thick, in another forming small pockets and discontinuous layers. Ores similar to those described, but in smaller quantities, are traceable westward on the slope of the same mountain for three miles, to within a mile of the Little Missouri River. Nowhere have they been found in sufficient quantities to make the deposits of any commercial value.

MONTGOMERY COUNTY.

General features.—The iron deposits of Montgomery county are mostly in its southern portion, and they follow the ridges of the Ouachita Mountains which pass from east to west through that part of the state. The nature and the mode of occurrence of the ores are the same as in the other counties in the region of the Ouachita Mountains.

The Meyer Creek claims.—Meyer Creek is a small stream rising southwest of Crystal Springs, and flowing southeast into Mazarn Creek. In 3 S., 22 W., section 16, it cuts a deep gorge through the novaculite ridge which passes in a zigzag course through this part of Montgomery county. On the part of the ridge that runs west from the creek, a few fragments of brown hematite, occasionally associated with hard, black manganese ore, occur, and several claims have been taken up under the delusion that the ore was all manganese. Similar materials

are occasionally seen in place in the novaculite, but the quantity is exceedingly small and of no commercial importance.

The Bud Jones claim No. 1.—The Bud Jones claim No. 1 is in 3 S., 23 W., section 22, the southeast quarter of the northeast quarter. This tract is about five miles west-by-south from the claims already described on Meyer Creek, and is on a ridge rising over four hundred feet above Mazarn Creek, which is less than a mile to the southwest. The gray novaculite forms the crest and upper slopes of the ridge, and the siliceous shale forms the lower slopes. On the south side of the mountain, in the gray novaculite, and just above the contact of that rock with the siliceous shale, is a deposit of iron ore dipping almost vertically.

The ore is massive, of a bright submetallic lustre, steel-gray color, and a reddish-brown streak. It has the physical properties of hematite, but chemically it differs from it in containing 8.05 per cent of water. It has already been described on page 67. The outcrop is mostly obscured by loose material, but where exposed, it has a maximum thickness of two feet. If it were stripped, it would probably be found to be wider in some places. The outcrop is traceable for about a hundred yards along the slope of the hill, and strikes in an easterly direction toward the summit. It could probably be traced further were it not covered by debris. The ore occasionally contains layers or masses of gray novaculite, and sometimes forms the cement of a breccia of novaculite fragments. It is undoubtedly an interbedded deposit at the contact of the novaculite and siliceous shale, or in the former near the contact. In the hollow at the foot of this mountain are numerous masses of this ore that have rolled from above, some of them weighing several hundred pounds. The ore is in too small quantities to be of value as a source of iron.

This claim was taken up on the supposition that the ore was manganese. The accompanying analysis by W. A. Noyes shows the composition of the ore :

Analysis of iron ore from the Bud Jones claim No. 1, Montgomery county.

Iron	61.99
Silica	1.58
Phosphorus	0.20
Manganese	0.04

The analysis shows the ore to be of good quality in its high percentage of iron and low silica, but to contain an injurious amount of phosphorus.

In the siliceous shale that borders the gray novaculite on either side, are found interstratified beds of ordinary brown hematite, from one to three feet in thickness, generally mixed with more or less shaly material. Sometimes the beds are entirely replaced by shale, while perhaps a few hundred yards further on they appear again, the transition often being sharp. This ore is in quantities too small and of too poor quality to be of value.

The relation of the different rocks to the different kinds of ore found on this property is shown in the accompanying figure 4, which represents a section in a north-south direction across the ridge on which the claim is situated. The deposits marked C represent the brown hematite in the siliceous shale. The deposit marked D is the ore at the contact of the shale with the novaculite, of which an analysis is given above. The continuation of the ore below the surface, as represented in the figure, is imaginary, as no mining has been done, but

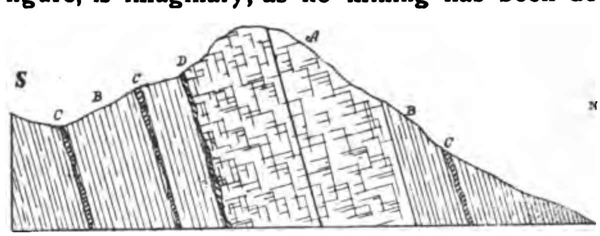

Figure 4. *North-south section through the Bud Jones claim No. 1, Montgomery county, showing the occurrence of the iron deposit.*

A. Gray novaculite.
B. Siliceous shale.
C. Iron deposits in the siliceous shale.
D. Iron deposit at the contact of the siliceous shale and the novaculite.
Horizontal scale: 1 inch=800 yards. Vertical scale: 1 inch=400 feet.

it shows the general direction of the downward extension of the deposits. The thickness of the ore beds as represented in the figure is greatly exaggerated, this being necessary in order to make the positions of the deposits clear.

The Bud Jones claim No. 2.—The Bud Jones claim No. 2 is in 3 S., 23 W., section 23, the southwest quarter. It is less than a mile south-by-east from the last locality. Fragments of iron ore, similar to the first kind described at the last place, are scattered over the surface. The ore is not seen in place, as the main deposit is concealed by loose material. The surface fragments are frequently made up of a mass of thin stalactitic branches, from a sixteenth to a quarter of an inch in diameter.

The Bud Jones claim No. 3.—The Bud Jones claim No. 3 is in 3 S., 23 W., section 29, the north half. This claim is on the north side of a novaculite ridge and half way up its slope. The gray novaculite forms the summit and upper part of the ridge; the siliceous shale forms the lower slope. The rocks all strike east-west and dip steeply to the north. A seam, two and a half feet in thickness, of a porous brown iron ore, occurs in the gray novaculite, and is often coated with a brilliant red ochre. Unlike most of such exposures, however, this deposit of ore is not interbedded with the rock, but dips at about 70° east, and strikes north and south directly across the stratification. On the slope of the ridge, the gray novaculite forms an almost vertical ledge for ten or fifteen feet above its contact with the siliceous shale, and then slopes upward more gradually. In the face of this ledge a cross section of the ore deposit is well exposed. Twenty feet above the shale the deposit thins out to a few inches in width. Sections of similar though smaller deposits, from one to twelve inches in thickness, are seen in the face of the ledge. Sometimes thin layers or small pockets of the same kind of ore follow the contact of the two rocks in the normal interbedded manner. The deposits across the bedding probably represent crevices filled with ore derived from the bedded deposits or from iron scattered through the surrounding rocks. The ore is in too

small quantities to be of value as a source of iron. The following analysis by W. A. Noyes shows the composition of this ore:

Analysis of iron ore from the Bud Jones claim No. 3, Montgomery county.

Iron	54.54
Silica	0.84
Phosphorus	1.79
Manganese	0.80

The analysis shows the ore to be of good quality in its high percentage of iron and low percentage of silica, but its value is injured by its large percentage of phosphorus.

The Dunney claim.—The Dunney claim is in 3 S., 23 W., section 30, the northeast quarter of the northeast quarter. It is about a half a mile west of the last claim and on the summit of the same gray novaculite ridge. The ore deposit consists of a breccia of soft, angular, novaculite fragments, from a fraction of an inch to six inches in diameter, cemented by a bright, submetallic, steel-gray iron ore.* The ore is generally in the form of thin seams, a fraction of an inch in thickness, cementing the rock fragments, though sometimes pure masses several inches in diameter are seen. Occasionally it is in mammillary or stalactitic forms, or in small, flat nodules stuck to the novaculite fragments. The breccia runs along the ridge, but rapidly thins out in either direction. This ore is too much mixed with the rock to be of value, and the quantity is too small to pay to concentrate it.

An examination of the breccia shows that, though the fragments of the rock are separated by thin layers of ore, the angles of any two pieces of rock directly opposite each other would almost always fit together if the ore were removed. It is probable, therefore, that the brecciation is caused by the shattering of the rock in place, and not by the cementing together of novaculite fragments indiscriminately mixed.

The Golden Gate claim.—The Golden Gate claim is in 3 S., 23 W., section 31, the northwest quarter. Here the same

*This ore is the one referred to on page 66 as representing the mineral turgite.

breccia is seen as at the last place, except that the iron ore has a brown, dull, earthy, porous appearance, instead of a bright submetallic lustre; a fact, however, which may be due to surface weathering. The thickness of the outcrop is not seen on account of the covering of loose material, but fragments of ore are scattered for a distance of over two hundred yards along the north slope of the mountain. Occasionally masses of pure ore are found, weighing from one to two hundred pounds.

Township 4 S., 24 W.—The main novaculite ridge of this region passes through township 4 S., 24 W., from northeast to southwest, in a series of zigzag folds. Small quantities of iron and manganese ores are found in the novaculite at many places in the hills, but both are in quantities of no importance whatever and do not require further mention.

Caddo Gap.—Caddo Gap is a deep gorge through which the Caddo River, in the western part of 4 S., 24 W., crosses one of the main novaculite ridges. Beyond, to the west, the ridge rises again to a height of 580 feet, and continues toward the head waters of the Little Missouri River.

In the ridge on the west side of the Caddo River, and immediately north of the village of Caddo Gap, a stain of iron occurs in the novaculite at the contact of that rock with the shale, on both sides of the ridge, and occasionally small masses of ore are seen. These exposures can be followed thence westward, but the quantity of the ore is insignificant and of no commercial importance.

"*S Crossing.*"—Such occurrences as those just mentioned at Caddo Gap, are again seen on a trail crossing the main ridge about two miles west-by-north from the village of Caddo Gap. The trail passes through a circuitous gorge, from which the name "S Crossing" has been derived. In places on the south slope of the mountain, on this trail, the novaculite is stained a deep rusty color, and contains thin seams and pockets of iron ore like that just described as occurring at Caddo Gap. These vary from one to eighteen inches in thickness and occur in a belt of novaculite about fifty feet wide. They are not in workable quantities.

*North Mountain.**—North Mountain is the name locally applied to the novaculite ridge running north-of-west in 4 S., 26 W., about two miles north of Fancy Hill Post-office. It is the continuation of the ridge at Caddo Gap. On the slopes of the mountain the iron and manganese stratum occurs in the gray novaculite, near its contact with the shale, and follows the strike of the rocks along the ridge. Both the iron and the manganese ores are in very small quantities, the latter especially so, and the ore-bearing stratum is usually marked only by a ferruginous stain or by small seams or bunches of iron ore.

The Burns claim.†—This one of the Burns claims is in 4 S., 26 W., section 18, the southwest quarter, and is on a low foothill of the main ridge lying to the north. The gray novaculite forms the south slope and the siliceous shale the north slope, their contact coming at the crest of the hill. Along this contact line numerous flat masses of a laminated, brown hematite, from three to twelve inches in thickness, are found among the loose rock. Very little stripping has been done and the main body of the ore is not exposed, so that the full thickness of the deposit cannot be seen, but the ore is probably limited in quantity and is of low grade.

A similar ore occurs in a hollow separating this hill from the mountain to the north, and in one place a bed ten feet thick was seen. In many other places in the neighborhood, both to the east and to the west, in the direction of the strike of the rock, similar though somewhat smaller outcrops occur. The ore intermittently blends into the shale and disappears.

Caddo Mountain.—Caddo Mountain bears east and west through the extreme southwestern part of 3 S., 26 W., and into 3 S., 27 W. It runs parallel to and on the immediate south side of the Caddo River, rising about 400 feet above it. The crest and the upper parts of the ridge are composed of gray novaculite, and the black siliceous shale occurs on the slopes. On the summit are numerous outcrops of a black or dark gray iron ore, with a bright submetallic lustre, frequently

*This name is also applied to several other ridges in the Ouachita Mountains.

†Mr. Burns has a large number of claims in Montgomery and Polk counties.

in globular, stalactitic, or mamillary forms. It is in thin seams and pockets, from a fraction of an inch to a foot in thickness, and generally forms the cement of a breccia of novaculite fragments. It decomposes on the surface into a brown, earthy ore. The mixture of ore and rock is from ten to forty feet in width. It was followed for two miles along the crest of the ridge and is doubtless traceable for a still greater distance. The amount of ore, however, in any one place is small, as the novaculite fragments compose by far the larger part of the ore-bearing stratum. The ore, though sometimes in small pockets free from rock, is generally in the form of thin layers or films in the novaculite.

The Crooked Creek region.—Crooked Creek runs west through the northern tier of sections of 4 S., 27 W., and then turns abruptly to the southeast, flowing thence into the Little Missouri River, in the same township. It forms one of the main forks of the Little Missouri River in this region of the head waters of that stream, and its valley is bordered by novaculite ridges. Several small pits have been sunk on the ridges on the outcrop of the iron and manganese stratum. Both ores are in small quantities of no commercial value.

POLK COUNTY.

General features.—The iron ores of Polk county are in almost all respects similar to those just described as occurring in Montgomery county. The ore is found either with, or in the same region as, the manganese ores of Polk county, which, as in the other counties of the Ouachita Mountains, have already been described in Vol. I of the Annual Report of the Survey for 1890. Only the iron ores will be mentioned here.

Leader Mountain.—Leader Mountain runs a little north-of-west in 4 S., 27 and 28 W., partly in Polk county and partly in Montgomery. It commences at the Little Missouri River and passes thence westerly to the waters tributary to the Cossatot River. A number of claims have been taken up along its course on the exposures of the iron and manganese stratum. The largest of the iron exposures yet found is on the J. Guy

Lewis claim. This claim is on Leader Mountain, about two and a half miles west of the line between Polk and Montgomery counties. A small cut has been made on a deposit of hard, brittle, brown hematite, of a shaly structure. The ore occurs as pockets and lenticular beds in the novaculite, the largest seen being a pocket two feet in diameter. Such deposits are scattered irregularly through the rock, on the summit of the mountain, over a breadth of about twenty feet. The ore is traceable in intermittent outcrops for half a mile east and west from the cut, and also occasionally beyond these limits. The ore is of too poor a quality and in too small quantities to be of value. Sometimes a few small masses of hard, steel-blue manganese ore occur in the iron ore, especially at its contact with the country rock.

The following analysis by A. E. Menke shows the composition of the iron ore on this claim:

Analysis of iron ore from the J. Guy Lewis claim, Polk county.

Iron	16.22
Silica	19.82
Phosphorus	0.778
Sulphur	0.137
Manganese	trace.

The analysis shows the ore to be too low in iron and too high in silica to be of any value.

Pointed Rock tunnel.—Pointed Rock tunnel is in 4 S., 28 W., section 19, and is the property of the Arkansas Development Company. A deposit of hard, laminated, brown hematite occurs here, interbedded in gray and black siliceous shale. The rocks stand vertically or dip at angles of from 70° to 80° to the north, and form part of a low hill. A tunnel has been run in at the foot of the hill, just above the level of a small creek, and follows the iron ore in the direction of the strike of the rock for about a hundred feet. The ore occurs in a series of parallel strata, from one to twelve inches in thickness, separated by similar strata of shale, or of clay which has resulted from the decomposition of the shale. The northern part of the hill is composed of the gray novaculite, and the

ore occurs near the contact of the shale with that rock. The rocks strike across the hill, and the ore can be traced for a distance of about a quarter of a mile over the summit and down to a creek on the other side. The alternating strata of iron ore and shale occupy together a belt varying from twenty to fifty feet in width. In places the combined thickness of all the ore strata, if brought together, would amount probably to over five or six feet; in others, it would not be a quarter of that thickness. Sometimes the ore in a given stratum runs out and is represented by rocks for a few feet, but it usually appears again beyond.

The following analysis by A. E. Menke shows the composition of the ore from this claim:

Analysis of iron ore from Pointed Rock tunnel, Polk county.

Iron	14.51
Silica	41.40
Phosphorus	0.191
Sulphur	0.082
Manganese	a little

The analysis shows the ore to be too low in iron and too high in silica to be of value.

Gillam Springs.—Gillam Springs are in 4 S., 30 W., section 22, the southwest quarter of the northwest quarter, on the Dallas and Centre Point wagon road, twenty miles, by the road, south of the former town. The property belongs to Mr. Asa Williamson, and consists of a series of small sulphur springs.

About a mile east of the springs, the brown hematite, which usually accompanies the siliceous shale, is seen in many places in that rock, in a series of strata from a few inches to several feet in thickness, alternating with similar strata of shale. Numerous such exposures occur on the western end of a ridge northeast of Gillam Springs, and in one place a surface exposure, between four and five feet in thickness, was seen. Larger outcrops are said to have been found and prospected in this neighborhood. Sometimes the same stratum is represented in one place by iron ore and in another by rock, and such oc-

currences often repeat themselves for several hundred yards. The ore is in most places, however, highly siliceous, and this fact, added to the variability of the deposits in their amount of ore, makes them undesirable as sources of iron.

Hannah Mountain.—Hannah Mountain is in 4 S., 29 and 30 W., and is one of the most prominent ridges in the novaculite belt of the Cossatot River. It runs from north of Tall Peak Mountain on the east, in a direction of a few degrees north of west to the Cossatot River, and thence beyond the Cossatot to the Brushy Creek fork of that stream, a total distance of over ten miles. Hannah Mountain east of the Cossatot River is known as East Hannah, and west of the river, as West Hannah.

There are numerous exposures of manganese and iron ores, similar to those already described, along the course of the ridge. The ores are generally at or near the contact of the novaculite with the siliceous shale. The outcrops follow along the mountain and vary in position with the contact of the rocks, at times rising to the summit, but more generally dropping a short distance on the slope, generally on the south side. The iron ore usually occupies a position similar to the manganese ore, but it also occurs in the shale lower down the mountain side. Several openings have been made on the manganese deposits and a few on the iron deposits of Hannah Mountain, those on the iron having usually been made under the impression that the ore was manganese. The only iron opening worthy of mention is on the High Peak of Hannah Mountain.

The High Peak of Hannah is the highest part of the Hannah ridge, and is about three miles east of the Cossatot River. On the south slope of the mountain, and probably about three hundred feet from the summit, is a deposit of brown hematite in the novaculite. The deposit is three feet in the widest part, and about two thirds of it is composed of ore, the rest being rock. It follows along the slope of the mountain for about ten feet, and beyond this, in both directions, it becomes thin and is often represented by only a stain. The ore is not in sufficient quantities to be of value.

To both the east and west of the High Peak of Hannah, on

the same mountain, small seams and nests of manganese and iron ores occur in the gray novaculite.

Buckeye and Shadow Rock Mountains.—Buckeye and Shadow Rock are names given to different parts of a novaculite ridge which runs parallel to and immediately north of Hannah Mountain, in 4 S., 28 and 29 west. In its eastern part, it is known as Buckeye Mountain, until within about four or five miles of the Cossatot River, and from that on to the river it is known as Shadow Rock Mountain. The ridge rises from five to eight hundred feet above the Cossatot River, and is separated from East Hannah Mountain by a deep ravine which marks the course of Short Creek, a tributary of the Cossatot.

A large number of claims have been taken on the exposures of the manganese and iron stratum on various parts of the mountain, and the principal iron claims are:

(1.) The Walston claim.—The Walston claim is on a spur of Buckeye Mountain known as Manganese Mountain. Layers of glossy black or dark brown iron ore (limonite, brown hematite), from two to six inches in thickness, are interbedded in the gray novaculite. The ore also runs across the stratification, in fractures in the rock. The deposit occurs on the crest of a small, local anticline, and the layers of the ore dip off on both sides of a small pit that has been made on it.

Another one of the Walston claims is near the last and at the point where Manganese Mountain joins the main Buckeye Mountain. Iron ore similar to that just mentioned has been found here in a small pit, now mostly filled up. It is said to have been in larger quantities than at the last place.

(2.) A short distance west of the last locality, on the main Buckeye Mountain and about four miles east of the Cossatot River, are several other claims. A stain of iron and manganese and occasionally a few small seams of those ores occur in the rock, but no large deposits have been found.

(3.) Two miles east of the Cossatot River and on the south slope of the ridge, small masses of manganese and iron ores are scattered through the loose rock. The ridge here is known as Shadow Rock Mountain.

Two hundred yards farther down the slope of the mountain, strata of brown hematite occur in the siliceous shale. There are fifteen feet of interbedded layers of brown hematite and rock, with an undulating dip of 60° to 80° north and a strike in an east and west direction, parallel to the ridge. Sometimes the iron ore composes the larger part of the deposit, but usually the latter is rock stained with iron, thus giving the impression that the ore is more plentiful than it really is.

(4.) About a mile east of the Cossatot River, and still on the southern slope of Shadow Rock Mountain, several outcrops of iron and manganese ores occur in the gray novaculite, at or near its contact with the siliceous shale. This ore-bearing stratum is known locally as the "Prince Edward lode," a name which is somewhat indefinitely applied to almost all the claims on this ridge from Manganese Mountain on the east to the Cossatot River on the west. The iron ore is sometimes associated with manganese ore, sometimes free from it. Both ores run irregularly through a stratum of novaculite, varying from three to five feet in width, and form from a tenth to a half the mass.

The C. C. Avant claim.—The C. C. Avant claim is in 4 S., 30 W., section 1, about a mile west of the Cossatot River, on the south slope of a novaculite ridge and about a quarter of the way from the summit. Here the ore-bearing stratum is represented mainly by iron ore, though small quantities of a black manganese ore sometimes occur. The iron ore is a brown hematite, and forms the cement of a brecciated novaculite, in which the rock masses vary from a fraction of an inch to six inches in diameter and are sometimes stained throughout by iron. This mixture of rock and ore has a width of about thirty feet on the slope of the mountain, but only a small part of it is composed of ore.*

The Arkansas Development Company.—The manganese mines of the Arkansas Development Company have already been described in Vol. I of the Annual Report of the Geological Survey

*The manganese claims of Mr. C. C. Avant have already been described in the Annual Report of the Survey for 1890, Vol. I, pp. 367–368.

of Arkansas for 1890. Below are given descriptions of some of the company's openings made on iron ore in the region west of the Cossatot River. The claims of this company at Pointed Rock tunnel, east of the Cossatot, have already been described on pages 98–99. No work is being done now on either iron or manganese ore, and no iron ore has ever been shipped from the company's properties.

Tunnel No. 2 is a little over a half a mile east-northeast of the Ward manganese mine, which is the property of the above mentioned company. The tunnel is twenty feet long and was run on a deposit of brown hematite, in a gray siliceous shale. The ore is interbedded in the rock in irregular pockets, from a few inches to a foot or more in thickness. It is laminated and has much the same structure as the enclosing shale, into which it blends both laterally and vertically. The quantity of the ore is very limited.

Two hundred yards northeast of this tunnel is a small pit on a similar ore in a similar rock. The ore frequently forms the cement of a breccia of fragments of the enclosing rock, and is irregularly scattered through a stratum three feet thick. The shale in contact with the ore is often much decomposed, existing in the form of a fine siliceous powder.

Little Manganese Mountain.—Little Manganese Mountain is the name given to the western end of the novaculite ridge running parallel to, and a mile south of East Hannah Mountain. Iron and manganese ores are found on it a mile east of the Cossatot River, where the mountain begins to slope down to the valley of that stream. The claim is owned by Mr. William Allen. The ridge here is composed mostly of gray novaculite, dipping at angles of from 45° to 60° north and overlain on the northern slope by the siliceous shale. At the contact of the novaculite with the siliceous shale are disconnected strata of brown hematite, associated with a smaller quantity of manganese ore, and varying from a fraction of an inch to four inches in thickness. The strata run sometimes continuously in the direction of the ridge for fifty or sixty feet, and then thin out, appearing again beyond. The manganese ore is in much smaller

quantities than the iron ore, and occurs in nodules and thin seams. As a rule, the iron cre seems to be largely confined to the contact of the novaculite and shale, while the manganese ore occurs not only there, but also extends into the novaculite, away from the contact line. Both ores are in quantities of no commercial importance.

CHAPTER VI.

THE IRON DEPOSITS OF SOUTHERN ARKANSAS.

(The southern part of Saline county, Dallas, Ouachita, Nevada, Hempstead and Lafayette counties.)

THE LOCATION OF THE DEPOSITS.

The iron deposits of southern Arkansas include the ores that occur in the flat or rolling country south and east of the line of the St. Louis, Iron Mountain and Southern Railway, and west of the Arkansas River. Under this heading, therefore, come the iron deposits of the southern part of Saline county, Dallas, Ouachita, Nevada, Hempstead and Lafayette counties. The ores in this region occur in a belt of country extending from Saline county on the northeast, in a southwesterly direction to the bluffs of the Red River bottoms in Hempstead county, an area of over a hundred miles in length and from one to over fifteen miles in width. The iron deposits, however, are not found continuously throughout this area, but only at intervals, and there are often many square miles of territory in which no ore at all occurs.

THE GEOLOGIC RELATIONS OF THE DEPOSITS.

The geologic position of the iron deposits of southern Arkansas is in the Eocene series of the Tertiary, and probably mostly below the Claiborne horizon of that series, although more or less iron is characteristic of almost all the Tertiary strata of the state. In eastern Texas, where the geologic position of the Tertiary iron ores is more easily defined than in Arkansas, two principal divisions of the Eocene contain noticeable quantities of ore: the lower one is the great series of sands and clays which forms the central part of the Eocene (the Timber Belt or Sabine River beds of the Texas section); the upper one is

the Claiborne glauconite that overlies these beds.* In Arkansas practically all the ores seem to correspond approximately to the horizon of the lower deposits of Texas, though it is possible that small quantities of ore exist in a horizon corresponding to the upper one in Texas, as iron ore in glauconite of uncertain position in the Eocene series is of not infrequent occurrence in southern Arkansas.†

The iron ores of southern Arkansas, and also those of the lower horizon in Texas, are not confined to one individual stratum, but occur in various positions in the beds of which they form a small yet characteristic part.

THE NATURE OF THE ORES.

Most all the iron ores of southern Arkansas are limonites, or brown hematites, in various physical forms, though small quantities of carbonate or spathic iron ore, also known as clay-ironstone, occur in some places. In fact, as will be shown in the next chapter, the carbonate ore was probably the original form of much of the present brown hematite. In the classification of the Texas brown hematites in the report referred to above, the ores were divided into three groups, distinguished by their physical structure; namely, (1) brown laminated ores, (2) nodular or geode ores, and (3) conglomerate ores, the last usually an unimportant product of the erosion of the first two and the cementing of their fragments. In Arkansas the typical brown laminated ore is wanting, as is also any large quantity of the conglomerate ore. The nodular or geode ore comprises the mass of the deposits, to which may be added the unimportant carbonate ore. Another variety of ore, however not known to exist in Texas, occurs in the Arkansas Tertiary strata. It

*For a more detailed description of the geologic relations of the iron deposits of eastern Texas, see First Annual Report of the Geological Survey of Texas, 1889, E T. Dumble, State Geologist, Preliminary Report on the Geology of the Gulf Tertiary of Texas from Red River to Rio Grande, by R. A. F. Penrose, Jr., pp. 65-84.

†For a more detailed account of the general geology of the Tertiary areas of Arkansas, the reader is referred to the Annual Report of the Geological Survey of Arkansas for 1888, Vol. II, the Neozoic Geology of Southwestern Arkansas, by R. T. Hill; to the Annual Report of the same Survey for 1889, Vol. II, the Geology of Crowley's Ridge, by R. E. Call; and also to the special report on the Tertiary geology of Arkansas now in preparation by Gilbert D. Harris.

is a pisolitic iron ore in the form of a bauxite (hydrous oxide of alumina often containing iron), highly charged with iron, and having the structure of a rusty brown mass of the globular bodies characteristic of bauxite. These globular bodies are about the size of peas, and hence the term *pisolitic*, from the Latin word, *pisum*, a pea.

Three varieties of ore may, therefore, be distinguished in the southern Arkansas region:

(1.) Nodular ore (brown hematite, limonite).

(2.) Pisolitic iron ore, or ferruginous bauxite.

(3.) Carbonate or spathic ore (clay-ironstone).

Of these three varieties, the nodular ore is the most important, and is also of better quality than any of the rest. It is characterized by the concretionary or nodular character of the masses composing the ore beds, though it sometimes occurs in mammilliary, stalactitic and botryoidal forms. The nodules are often, and in some places generally, hollow, forming geodes, or "iron pots," varying from a fraction of an inch to several feet in diameter. The nodules are frequently cemented together by ore, or by a ferruginous sandstone, and form a more or less continuous bed, while at other times they occur loose in the enclosing sands and clays. They are generally partly filled with a yellow, brown or red clay and sometimes by a ferruginous ochre. They vary from yellow and brown to almost black in color, and the geodes are usually lined on the inside by a brilliant black gloss. Sometimes the outer part of a geode is an amorphous mass, while the inside exhibits the fibrous character of certain hydrous sesquioxides of iron. Frequently branching or dendritic protrusions of ore extend from the inside surface of a geode into the hollow interior. The more solid nodules have a concentric structure, the individual layers being often separated by narrow spaces which generally contain more or less earthy matter. Plates III and IV, in the present chapter and succeeding one respectively, illustrate the nature of the geodes.

The nodular ores vary considerably in chemical composition.

Analyses of iron ores from southern Arkansas.

Number.	LOCALITY.	Iron.	Silica.	Phosphorus.	Sulphur.	Manganese.	Analyzed by
	SALINE COUNTY (southern part.)						
1	R. W. Worthen tract, 3 S., 13 W., Sec. 6.......	40.94	30.26	0.070	....	Trace.	Brackett.
2	" " " " " " " "	22.57	2.96	0 193	0.548	A little	Menke.
3	Young tract, 2 S., 14 W., Sec. 33, N. E.........	21.10	28.86	0.110	0.178	A little	"
4	Frank Davis tract, 2 S., 14 W., Sec. 1	20.98	2.12	0.262	0.452	Trace.	"
5	Claiborne tract, 2 S., 14 W., Sec. 10...........	14.34	3.46	0.124	0.274	A little	"
6	Wm. Herr tract, 2 S , 14 W., Sec 3, E ½, S. W ...	21.96	6.68	0.317	0 041	"	"
	DALLAS COUNTY.						
7	Griswold's mill, 10 S., 16 W., Sec. 4............	30.67	40.48	0.704	....	None.	Brackett.
8	" " " " "	37.73	25.87	0.225	.....	Trace.	"
	OUACHITA COUNTY.						
9	Five miles west of Camden, 12 S., 18 W	26.15	52.16	0.588	.....	None.	"
10	Wm. Brown tract, 12 S., 18 W......	35.68	35.95	0.280	.....	None.	"
	NEVADA COUNTY.						
11	Vicinity of Rosston, 13 S., 21 W	57.17	4.27	0.225	.....	Trace.	"
12	" " " "	50 20	10 65	0.424	....	Trace.	"
13	" " " "	38.80	26.57	0.119	.....	None.	"
14	" " " "	30.88	50.63	0.223	.....	"	"
15	" " " "	22.08	58 73	0.085	.....	"	"
	HEMPSTEAD COUNTY.						
16	Eight miles north of New Lewisville	26.47	52.10	0.201	.....	None	"
17	" " " " " "	27.31	53.32	0.136	..	"	"
	LAFAYETTE COUNTY.						
18	Boyd Farm, near Lewisville	38.13	26.78	0.139	....	None.	"
19	" " " "	19.68	65.82	0.137	..	"	"

As will be seen by the accompanying table of analyses* they range from less than 20 per cent to over 50 per cent in iron, from 2 per cent to over 30 per cent in silica, and from 0.07 per

*Analyses Nos. 1, 2, 3, 11 and 12 represent nodular ores.

cent to over 0.4 per cent in phosphorus. The phosphorus in all the nodular ores is too high to allow them to be used for Bessemer steel; and even if they were found in sufficient quantities to pay for mining they could only be sold as non-Bessemer ores (see pages 8–10.)

The pisolitic ore, or ferruginous bauxite, referred to above, usually occurs in the neighborhood of the exposures of syenite (commonly called granite) which are numerous in Pulaski county and in the eastern part of Saline county, and it has possibly been derived largely from that rock.*

The deposits are usually associated with, and often interbedded in, Tertiary sands, showing that they were formed during Tertiary times. They generally lie on or near exposures of syenite. The ore often occurs in beds of probably over ten feet in thickness, covering considerable areas, but, as will be seen by the accompanying table of analyses,† the average contents of iron is too low and the alumina too high to allow the material to be of value as a source of iron. The iron in it varies from 5 per cent to rarely as much as 50 per cent, the silica from 2 to 15 per cent, the phosphorus from 0.1 to over 0.3 per cent, and the alumina from over 24 to over 50 per cent. A large amount of alumina in an ore makes it refractory and difficult to use in a furnace; and the percentage of this constituent in the pisolitic iron ore (ferruginous bauxite) of southern Arkansas would prevent its utilization as a source of iron.

The chemical composition of bauxite is represented by the formula $(Al.Fe)_2O\ (HO)_4$ in which the aluminum and iron may replace each other in various proportions. In the ordinary Arkansas bauxite the iron is low, rarely going over 10 per cent; but in the pisolitic iron ore, or ferruginous bauxite, a considerable part of the aluminum has been replaced and the

*For a fuller description of the Arkansas bauxites in Pulaski and Saline counties see: Annual Report of the Geological Survey of Arkansas for 1889, Vol. I, by J. C. Branner; and the same authority in the American Geologist, 1891, Vol. VII, p. 181; also Annual Report of the Geological Survey of Arkansas for 1890, Vol. II, by J. Francis Williams.

†Analyses 4, 5 and 6 represent samples of pisolitic iron ore.

iron sometimes runs up to over 30 per cent and in rarer cases to over 50 per cent.*

The carbonate ores are usually impure and rarely contain as much as 30 per cent of iron. They are too low grade to be of value, and besides, they occur in only very small quantities. They generally form the kernels of masses of brown hematite, and probably represent the source of that ore, as will be more fully explained in the next chapter.

Besides the varieties of ore just described, large deposits of brown ferruginous sandstone occur in the southern Arkansas region. These represent local areas of sand hardened by the percolation of ferruginous solutions, and they pass by abrupt gradations, both laterally and vertically, into loose sands. Sometimes brown ferruginous conglomerates, composed of siliceous pebbles in a sandy cement, also occur. The sandstones and conglomerates are often in much larger deposits than the iron ores and are locally mistaken for good ore, thereby giving a false impression of the abundance of the latter. Such materials† are too low in iron and too high in silica to be of any commercial value as a source of iron.

THE MODE OF OCCURRENCE OF THE ORES.

The nodular ore, which is the most important variety of iron ore in southern Arkansas, is interstratified with the Eocene sands and clays of the region, and occurs in beds varying from a few inches to three feet or more in thickness. The ore beds and associated strata lie almost horizontally, with an occasional slight dip southward. Sometimes several practically horizontal ore beds occur in the same group of strata, and are separated by beds of sand and clay from a few inches to many feet in thickness.

The region in which the iron ore occurs is a comparatively low country with elevations rarely reaching over five hundred

*Whether the presence of large quantities of iron in this bauxite is due entirely to a chemical replacement according to the formula given above, or partly to a mechanical admixture of ferruginous materials with a bauxite lower in iron, has not yet been demonstrated. It is probably due to both causes combined.

†These materials are represented in the table of analyses by Nos. 9, 14, 15, 16, 17 and 19.

feet obove the sea level. The strata of the region are all of a soft incoherent nature, with the exception of the iron ores and the beds of sandstone already described. These harder materials, therefore, have been largely instrumental in moulding the topography of the country during erosion. The usual topography, where the harder materials are absent, is almost flat or gently rolling. Where the ore and sandstone are present, however, the region is much more broken, and is composed of abrupt hills and ridges, flat on top and sloping off rapidly towards the creek and river bottoms. Though these hills are rarely over one or two hundred feet above the surrounding drainage, they are in marked contrast with the usual Tertiary topography, and are locally known as mountains. Their form has been regulated by the harder strata, which, resisting erosion better than the associated sands and clays, have protected the beds immediately under them while those above them have generally been largely, and sometimes altogether, removed. As a result of this erosion, the iron ores, as well as the sandstones, often cap the hills or occur near the summits; though of course, where there is a series of harder beds, one above the other, and separated by beds of sand and clay, the lower ones may appear well down the hills or even in the hollows. Occasionally a covering of sand or clayey sand still overlies the harder beds on the summits, and in such cases the ore or sandstone is seen only where it crops out on the upper slopes, forming a rocky rim around the hills or along the ridges.

The accompanying ideal section, figure 5, shows the general mode of occurrence of the iron ores.

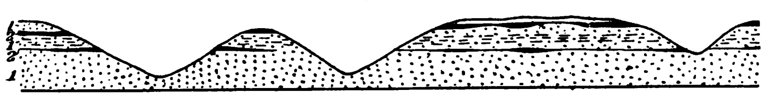

Figure 5. *Ideal section showing the mode of occurrence of the Tertiary iron ores.*
1. Sands and clays.
2. Ore beds.

Though the Tertiary iron ores occur over a large area in Arkansas, they are scattered, and the better grades of ores are rarely found in large quantities in any one place. The large

beds of sandstone and low grade earthy ores common in southern Arkansas are often mistaken for good ores, and this delusion has given people a false idea of the quantity of the latter. Such materials are described later in treating the region west of Camden and north of New Lewisville. The quantity of the better ore is small, and, though it is not impossible that it may in some places be found to occur in somewhat larger deposits than are at present known, it is improbable that any very large quantities will ever be discovered.

THE COMMERCIAL VALUE OF THE DEPOSITS.

From what has been said of the nature and mode of occurrence of the iron ores of southern Arkansas, the following facts are evident: all the ores, with the exception of the nodular ores, are of too poor quality to be of value. Large bodies of a ferruginous sandstone or conglomerate, and of a very sandy, brown hematite ore, are numerous in the region and are usually mistaken for good ore, but they are entirely worthless as sources of iron. The nodular ores contain too much phosphorus to be classed as Bessemer, but some of them are of very good quality for non-Bessemer ores. They occur, however, in deposits which are limited when it is considered that a large amount of ore is necessary to support an iron mining industry. They are from eight to fifteen miles from the nearest railway facilities, which are the St. Louis, Iron Mountain and Southern, and the St. Louis and Southwestern Railways. Limestone would have to be brought from an outside source, at distances of probably from fifty to a hundred miles. The ores are near the surface, however, and easily mined; and there is a large amount of timber fit for making charcoal in the vicinity; so that it is not impossible, in view of these advantages, that a small iron industry might, under especially favorable conditions, be supported on the better class of the ores of this region.

THE SOUTHERN PART OF SALINE COUNTY.

General features.—The iron ores of the northern part of Saline county, in the Ouachita Mountains, have already been

described in chapter V; but far more numerous deposits of iron ore occur in the Tertiary region in the southern part of the county. Most of them lie to the east and south of the town of Benton. The nature, mode of occurrence and commercial value of the ores have been treated in the preceding paragraphs.

The R. W. Worthen tract.—The Worthen tract is in 3 S., 13 W., section 6, about eight miles southeast of Benton. Several small prospecting pits have been made, but no ore has been shipped. The property consists of a series of low but abrupt hills and ridges separated by narrow ravines. The ore either caps the hills and ridges in horizontal beds or lies within a few feet of the summits. The ore-bearing formation varies from one to twenty-five feet in thickness, though in the cases where it is more than two or three feet thick, it is not all solid ore, but consists of layers of ore separated by layers of sand and sandy clay. The sand is usually red or mottled red and white.

The ore is not continuous on the hills, but alternately runs out and appears again; nor is it equally distributed throughout the sandy strata that contain it, but it occurs in patches and segregations.

Instead of being capped with iron ore the hills are frequently capped with a dark brown, highly ferruginous sandstone, often containing rounded siliceous pebbles from a fourth of an inch to two inches or more in diameter. This material is worthless as an ore, for it contains probably over 60 per cent of silica, yet it is commonly mistaken for good ore, and therefore gives a false impression as to the quantity of ore on the property.

The better class of ore is a brown hematite, varying considerably in character. Sometimes it is in layers, brown or yellow in color, and either dense or earthy and sandy. At other times it is in geodes, or "iron pots," from one inch to two feet in diameter, with a concentric structure, yellow or brown color, and often a glossy, black, mammillary surface inside. Though these masses of ore are usually hollow, they sometimes contain kernels of heavy, compact, gray carbonate of iron or clay-ironstone. The kernel and the outer part blend into each

other and point to the origin of the brown hematite crust from the clay-ironstone, as will be more fully explained in the next chapter. Generally both the massive, and the "pot" ore are associated together in the same bed.

Though the ore on this property is sometimes fairly good, it is often highly siliceous, containing sand in considerable quantities. It may be said, however, that there is more ore in sight on the Worthen tract, than on any other seen in the southern part of Saline county. The following analyses, the first by R. N. Brackett, the second by A. E. Menke, show the composition of average samples of the ore:

Analyses of iron ore from the R. W. Worthen tract, Saline county.

Iron	40.94	22.57
Silica	30.26	2.96
Phosphorus	0.07	0.198
Sulphur	——	0 548
Manganese	tiace	a little

The analyses show both samples to be low in iron, and the first sample to be high in silica, though somewhat better samples could be gotten from the property.

Smaller deposits of ore, sandstone and conglomerate, similar to those on this property, occur at many points between this place and Benton.

The Young tract.—What is commonly known as the Young tract is in 2 S., 14 W., section 33, the northeast quarter. Several small pits have been made on deposits of iron ore much like those already described on the last mentioned property. The ore lies horizontally and is capped by sand from a few inches to several feet in thickness. The ore bed is not continuous, but alternately appears and disappears. It varies from one foot to over three feet in thickness.

The following analysis by A. E. Menke shows the composition of a sample of the ore from this property:

Analysis of iron ore from the Young tract, Saline county.

Iron	21.10
Silica	23.86
Phosphorus	0.110
Sulphur	0.178
Manganese	a little

The analysis shows the ore to be too low in iron and too high in silica to be of value, though a better grade ore might be found on the property.

In one of the small pits a bed of nodular brown hematite over three feet in thickness is exposed. The ore is capped by a layer, from six to twelve inches in thickness, of a ferruginous conglomerate containing rounded siliceous pebbles. The nodules of ore are from eight to twenty-four inches in diameter, and almost always the larger ones contain kernels of gray clay-ironstone, often more than a foot in diameter. The smaller ones are often hollow and contain a red clay and sometimes an ochre, both of which are the residual products from the decay of the clay-ironstone.

A similar ore, but in thinner beds, occurs on several other parts of the property.

3 S., 14 W., Section 28.—In the northwest quarter of the southeast quarter of this section, a pit about twenty feet deep has been sunk for iron ore. The upper eighteen feet pass through a mottled sandy clay containing nodules and seams of brown hematite, and the lower two feet are in a dark chocolate colored clay.

The Frank Davis tract.—The Davis tract is in 2 S., 14 W., section 1. A pit twenty feet long, eight feet wide and about six feet deep has been sunk on a hard, dark reddish brown, ferruginous bauxite known as pisolitic iron ore. The material is composed of a mass of globular or spherical bodies about the size of peas, with a marked conchoidal fracture. In the bauxite are irregular masses, from an inch to a foot or more in diameter, of a dark brownish green material composed of minute pisolitic grains. The syenite ("granite") crops out near the deposit.

The following analysis by A. E. Menke shows the composition of the ore from this property:

Analysis of pisolitic iron ore from the Davis tract, Saline county.

Iron	20 98
Silica	2 12
Phosphorus	0.262
Sulphur	0.452
Manganese	trace
Alumina	44.82

The analysis shows the material to be too low in iron and too high in alumina to be used as an iron ore. The large percentage of alumina would destroy the value of the ore, even if the iron were higher. (See page 109)

The Claiborne tract.—The Claiborne tract is in 2 S., 14 W., section 10. A small pit, about ten feet square and five feet deep, has been made on a pisolitic ore somewhat similar to that on the Davis tract just described. The ore is often sandy and lies on the top of a low syenite ridge.

The following analysis by A. E. Menke shows the composition of the ore:

Analysis of pisolitic iron ore from the Claiborne tract, Saline county.

Iron	14.34
Silica	3.46
Phosphorus	0.124
Sulphur	0.274
Manganese	a little
Alumina	50.83

The analysis shows the material to be too low in iron and too high in alumina to be of value as an iron ore. The large percentage of alumina would ruin the value of the ore, even if the iron were higher. (See page 109.)

The Wm. Herr tract.—The Herr tract is in 2 S., 14 W., section 3, the east half of the southwest quarter, about a mile and a half south of Bryant. A shallow stripping has been made on an ore somewhat similar to that at the last locality, except that it contains less iron and more sand.

The following analysis by A. E. Menke shows the composition of the ore :

Analysis of pisolitic iron ore from the Wm. Herr tract, Saline county.

Iron	21.96
Silica	6.68
Phosphorus	0.817
Sulphur	0.041
Manganese	a little
Alumina	24.47

The analysis shows the material to be too low in iron and too high in alumina to be of value. The large percentage of alumina would destroy the value of the ore even if the iron were higher. (See page 109.)

Other localities in the southern part of Saline county.—Ores similar to those already described occur in many other places in southern Saline county. In 2 S., 14 W., and probably in section 2, on the Little Rock and Camden wagon road, half a mile northeast of the Hurricane Creek crossing, a material somewhat like that just described on the Herr tract, but of still lower grade, has been prospected in a few pits. Deposits of the same nature occur on several other farms in the same region.

DALLAS COUNTY.

General features.—Iron ores occur in several places in Dallas county. Some of the deposits are like those already described, while others differ from them in being associated with glauconite (greensand). One of the best known localities is that at Griswold's Mill.

Griswold's Mill.—Griswold's Mill is 10 S., 16 W., section 4, on Tulip Creek, a mile below the confluence of its two forks. The bluffs of the creek, on the west bank, rise abruptly for over twenty-five feet above the water, and are composed largely of a bed of dark green glauconite (greensand). Interbedded with the glauconite are thin lenticular layers and masses of a hard gray or greenish gray carbonate of iron, or clay-ironstone, from one to four or five inches in thickness. The glauconite bed is also cut in various directions by a network of seams of a hard, brittle, brown hematite (limonite), from a fraction of an inch to a couple of inches or more in thickness.

On a weathered surface the glauconite assumes a peculiar structure of spherical or nodular masses of the original bed, similar in a marked degree to the spherical weathering of many igneous rocks. The masses are surrounded by incrustations of brown hematite or hard rusty glauconite, which are doubtless due to the oxidation of the clay-ironstone and of the glauconite itself. Perhaps the carbonic acid liberated during the oxidation of the clay-ironstone has been an important factor in the decay of the glauconite. The spherical masses of glauconite vary from a few inches to several feet in diameter, and show a peculiar concentric structure, as more fully illustrated in plate II, made from a photograph. The two figures in the plate represent weathered masses of glauconite, which had rolled from the face of the bluff. The figure on the right shows the exterior form of the nodules and the way they scale off in spherical layers. This mass is about five inches in diameter. The mass on the left is eight inches in diameter, and has been cut in two so as to show the concentric structure inside of the nodules. The interiors of the nodules have the original green color of the glauconite, though this is obscured on the surface by the rusty brown crust.

It is commonly supposed in the neighborhood of Griswold's Mill that the whole bluff of glauconite, on account of its rusty appearance, is good iron ore. The following analyses of two samples of this ore, made by R. N. Brackett, show that it is of too low grade to be of any value, while the better ore mentioned above is in too small quantities to work.

Analyses of iron ore from Griswold's Mill, Dallas county.

Iron	30.67	37.73
Silica	40.48	25.87
Phosphorus	0.704	0 225
Manganese	none	trace

The analyses show that the materials contain too little iron and too much silica to be of value as iron ores.

OUACHITA COUNTY.

General features.—The iron ores of Ouachita county are mostly west of the Ouachita River, in the region between the

MASSES OF WEATHERED GLAUCONITE, DALLAS COUNTY.

town of Camden and the Nevada county line. The ores are somewhat similar to those already described in Saline county.

The Camden and Prescott road.—On the Camden and Prescott wagon road, about five miles west of Camden, and in 12 S., 18 W., thin layers of sandy brown hematite, from one to six inches in thickness, occur in a cut in the road. The ore is interbedded with a yellow or rusty brown sand containing grains of glauconite. Occasionally parts of the sand bed have become hardened and are intersected by thin layers of ore. The sand is often in this condition for a thickness of two or three feet, and, on account of its rusty appearance, is commonly mistaken for iron ore. The material contains too little iron and too much sand to be of value, while the thin layers of better ore are too few to be worked.

The following analysis by R. N. Brackett shows the composition of a mixed sample of both materials as they came out of this bank:

Analysis of iron ore from near Camden, Ouachita county.

Iron	26.15
Silica	52.16
Phosphorus	0.588
Manganese	none

The analysis shows the material to be worthless as an iron ore on account of its low percentage of iron and high percentage of silica.

On the north side of the Camden and Prescott road, about six miles west of Camden and in 12 S., 18 W., a deposit similar to that just described, occurs on the top and slopes of a ridge running parallel to the road. The so-called ore is earthy and sandy, and represents a hardened glauconitic sand. Masses of this material from one to two feet in thickness occur on the slopes of the ridge.

The William Brown tract.—The Brown tract is half a mile east of the last mentioned locality, on the same ridge and in 12 S., 18 W. Large quantities of a material somewhat similar to the ore found there occur on this property. Masses of it, sometimes three feet or more in diameter, cover the top and the

slopes of the ridge, and can be traced along it in either direction. The masses have come from a bed covered by a thin layer of gray sand near the crest of the ridge. The material often has a peculiar brecciated appearance, as if it consisted of fragments of ore in a sandy cement. Though this ore is in considerable quantities it is of too low a grade to be of value.

The following analysis by R. N. Brackett shows the composition of this ore:

Analysis of iron ore from the William Brown tract, Ouachita county.

Iron	35.68
Silica	35.95
Phosphorus	0.280
Manganese	none

The analysis shows that the ore contains too little iron and too much silica to be of value.

NEVADA COUNTY.

General features.—The iron ores of Nevada county occur mostly in the region of Caney Creek, in the central part of the county. Some of the ores are of fairly good quality for non-Bessemer brown hematites, but such ores are in small quantities, while the so-called ores which are in large quantities, are simply ferruginous sandstones of no commercial value.

Rosston.—The best exposures of iron ore, so far as known, in Nevada county, are within a radius of two or three miles of the village of Rosston. The road running south from Prescott crosses Little Caney Creek about thirteen miles south of that town, and from there to Big Caney Creek, a distance of about three miles, iron ore occurs in many places, especially in the neighborhood of Rosston, on the farms of E. T. McDaniel and others, in 13 S., 21 W.

The best ore occurs on or near the tops of somewhat abrupt hills and circuitous ridges, rising from forty to over seventy-five feet above the surrounding drainage. The ore is either directly on the surface, or is overlain by from a few inches to several feet of white or buff-colored sand. Below the ore there is a gray,

LIMONITE GEODES, NEVADA COUNTY.

red, yellow or mottled, sandy clay. The ore occurs in nodules and disconnected layers following the planes of bedding, and varying from an inch to over a foot in thickness; though the ore is so rarely seen except in broken fragments, that it is generally difficult to determine exactly how thick the deposit is. Lower down on the hills, and lying horizontally like the ore, are beds of rusty red or brown sandstone, often over three feet in thickness, and locally mistaken for iron ore. Sometimes two or more of such sandstone beds crop out on the slopes of the hills and are separated by strata of sand and sandy clay. The rock is generally soft and friable though sometimes it is hard. Occasionally it has the appearance of a sandy conglomerate made of fragments of ore and sandstone in a rusty, sandy cement. These materials, like the true ore, sometimes cap the hills, and in fact the good ore is often replaced by the sandstone, or occurs as hollow nodules in that rock.

Besides the main ore and sandstone beds, there are numerous minor thin layers of both these materials.

The characteristic feature of all the less silicous ore in this region is its geode or "pot" character; the geodes vary from one to ten inches or more in diameter, are flat, round or angular, and are frequently cemented together in a solid mass. The geodes generally have a concentric structure, and are usually partly filled with a red, yellow or brown clay. The insides of the geodes are generally glossy black, and often thin partitions or dendritic protrusions of ore extend into the hollow interiors. The accompanying plate III illustrates the nature of the geodes. The specimens have been broken open in order to show the character of the interiors. The two lower masses are the halves of one geode, while the upper mass is a half of another geode. Both of the geodes measure about eight inches in diameter.

Though the total amount of ore in this region is considerable, there is comparatively little of it in any one spot; while the impure, earthy materials and the rusty sandstones which occur in considerable quantities, and which are usually mistaken for ore, are of too low grade to be of value as a source of iron.

The following five analyses by R. N. Brackett show the composition of the different varieties of ore in this region:

Analyses of iron ores from near Rosston, Nevada county.

Iron	57.17	50.20	38.80	30.88	22.08
Silica	4.27	10.65	26.57	50.63	58.73
Phosphorus	0.225	0.424	0.119	0.228	0.085
Manganese	trace	trace	none	none	none

The first two analyses represent good non-Bessemer ores; the last three analyses represent the more siliceous ores, and show them to be too low in iron and too high in silica to be of any value.

HEMPSTEAD COUNTY.

General features.—Iron ores occur in many parts of Hempstead county. They are usually highly siliceous and are often in the form of either ferruginous sandstones or conglomerates, of no commercial value as sources of iron.

The Lewisville and Hope road.—Eight miles north of New Lewisville, on the Lewisville and Hope wagon road, just north of the boundary line of Hempstead and Lafayette counties, a ridge rises over a hundred feet above the surrounding lowlands. It is capped with a brown or yellow friable sandstone in a bed probably from six to ten feet in thickness, though the broken character of its outcrop renders its exact thickness uncertain. The sandstone, as seen on the slope of the ridge, is underlain by a conglomerate of quartz pebbles in a ferruginous, sandy cement, forming a bed probably fifteen feet or more in thickness. This in turn is underlain by sands and clays. Both the ferruginous sandstone and the conglomerate are often mistaken for iron ore, but they contain too little iron and too much silica to be of any value whatever as sources of iron. The following two analyses by R. N. Brackett show respectively the composition of average samples of the sandstone and of the conglomerate:

Analyses of iron ores from Hempstead county.

Iron	26.47	27.31
Silica	52.10	58.32
Phosphorus	0.201	0.186
Manganese	none	none

The analyses show that the materials contain too little iron and too much silica to be of value as iron ores.

LAFAYETTE COUNTY.

General features.—The iron ores of Lafayette county occur mostly in the northern part, near the Hempstead county line, and also in the region of Bodcaw creek. They are much like those of Hempstead county just described, though small quantities of a somewhat better ore occur in the Bodcaw region.

The Lewisville and Hope road.—On the Lewisville and Hope road, six or seven miles north of New Lewisville, ferruginous sandstones and conglomerates, similar to those just described in Hempstead county, but in smaller beds, occur in several places. As they are of no possible value as ores, they do not require further mention.

The Boyd farm.—The old Boyd farm is about eight miles northwest of New Lewisville, on the east side of the Red River. Ferruginous sandstones and conglomerates occur on several of the hill tops which form the bluffs of the river bottoms, and are usually mistaken for iron ore.

The following two analyses by R. N. Brackett represent the composition of the ores from this property:

Analyses of iron ores from the Boyd farm, Lafayette county.

Iron	38 13	19.68
Silica	26 78	65 82
Phosphorus	0.189	0.187
Manganese	none	none

The analyses show that the materials contain too little iron and too much silica to be of value as iron ores.

Bodcaw creek.—About ten miles northeast of New Lewisville, on a sandy hill rising about sixty feet above the surrounding lowlands, are found loose masses of brown hematite. The ore has a concentric structure, and is sometimes in the form of geodes. It is of fairly good quality. The masses vary from a few inches to a foot or more in diameter. They were nowhere seen in large quantities.

CHAPTER VII.

THE ORIGIN OF THE TERTIARY IRON DEPOSITS OF SOUTHERN ARKANSAS.*

GENERAL STATEMENT.

The nature and mode of occurrence of the Tertiary iron ores of southern Arkansas have already been described in the preceding chapter (pages 106–112). It is the object of the present chapter to show how and from where the iron in them was derived, and how it was deposited. It will be attempted to show that the deposits, during their formation, went through the following stages:

(1.) The derivation of the iron from the decay of the rocks in the drainage area of the sea, which, in Tertiary times, occupied the position of the present Gulf of Mexico.

(2.) The solution and transportation of the iron in the form of soluble organic and inorganic salts.

(3.) The precipitation of the iron as oxide or carbonate, in lagoons or bogs along the coast.

(4.) The segregation, as carbonate (clay-ironstone), of the iron precipitated in the above forms.

(5.) The conversion of the carbonate into the hydrous sesquioxide of iron (limonite) after the lagoons on the coast of the Tertiary sea had been elevated into a land area.

SUMMARY OF THE NATURE AND OCCURRENCE OF THE ORES.

The Tertiary iron ores of southern Arkansas are mostly limonites,† though small quantities of carbonate ore also occur. The limonites are generally more or less nodular in character,

*The present discussion of the Tertiary iron ores of southern Arkansas does not include the pisolitic iron ores, or ferruginous bauxites, described on page 107. These ores, though of Tertiary age, had a special mode of origin (see page 109), and differ in that respect from the other iron ores in the Tertiary strata of Arkansas.

†For the use of the term limonite in the present discussion, see foot-note, page 8.

the nodules being either loose in the enclosing strata of clay or sand, or else cemented into a solid bed by a ferruginous matrix. The nodules are sometimes composed of a series of loose concentric layers, at other times they are hollow, forming geodes. The ore deposits vary from a few inches to two feet or more in thickness, and are interbedded with the Tertiary sands and clays. The ore and the associated strata are practically horizontal, and the ore usually occurs at or near the summits of flat-topped hills and ridges. Sometimes several practically horizontal ore beds occur in the same group of strata, and are separated by beds of sand and clay from a few inches to many feet in thickness. In the same region as the iron ores, there frequently occur beds of hard or soft ferruginous sandstone, or of a conglomerate of siliceous pebbles in a ferruginous sandy matrix. These beds vary from a few inches to fifteen or more feet in thickness, and are of irregular distribution, often blending abruptly, both vertically and laterally, into loose sands or gravels. Like the iron ores, they often form the summits of flat-topped hills, though frequently hills containing iron ore on the top have sandstone beds at a lower level. Some of the sandstones and conglomerates are deposits interbedded in the Tertiary strata, and therefore of Tertiary age, but others are of a much later date, and are probably Pleistocene, or still younger deposits, hardened by the percolation of iron-bearing solutions. (See pages 133–134.)

The iron ores of southern Arkansas form a part of an ore-bearing belt which characterizes certain horizons of the Tertiary strata from eastern Texas on the west, intermittently through southern Arkansas and parts of northern Louisiana,* into Mississippi† (see pages 105–106).

CONDITIONS DURING THE DEPOSITION OF THE ORES.

Littoral environments.—In inquiring into the origin of the iron ores of the Tertiary strata of the Gulf basin, it is necessary to

*See Supplementary and Final Report of a Geological Reconnoissance of the State of Louisiana, by E W. Hilgard, 1873; also, The Iron Ore Region of Northern Louisiana and Eastern Texas, Lawrence C. Smith, Congressional Documents, 1888.

†The Geology and Agriculture of the State of Mississippi, E. W. Hilgard, 1860.

consider the conditions surrounding the deposition of the great series of alternating sands and clays, which comprises the mass of the strata. That they are a littoral formation is proved by the character of the organic remains enclosed in them; by the not infrequent occurrence of pebble beds, especially in Arkansas; by the lateral blending of marine and brackish water or lagoon deposits; and by the rolled and rounded character of many of the shell fragments, shaped as if by continued beating on or near a sea beach. Again, the frequent occurrence of extensive beds of lignite at various horizons would indicate conditions of deposition which permitted numerous ready transitions from marine to land or coastal lagoon conditions. Such conditions doubtless gave rise to large areas of swamps and shoals along the coast of the Tertiary sea, probably not unlike those now seen in places on the coasts of Florida and Louisiana, and around the lower part of the Sabine River in Texas. The waters from the land drained into these basins, and probably often remained in a semi-stagnant state for considerable periods, undergoing more or less evaporation.

Sources of the iron.—The waters emptying into the Tertiary sea doubtless all contained more or less iron in solution. The iron was derived from the decay of the iron-bearing minerals and rocks of the land, and was taken into solution by acids derived from the decay of organic matter, from the oxidation of such minerals as iron pyrites, and from other sources. These solutions were taken up by surface waters and carried down the various water-courses to the coast.

The rocks forming the drainage area of the Tertiary sea in question all contained greater or less quantities of iron-bearing materials: the glauconite of the Upper Cretaceous of Texas, and the Paleozoic and pre-Cambrian rocks to the west of the Cretaceous area were sources of iron to the circulating waters; while the Carboniferous and Silurian shales and sandstones of Indian Territory, and of central and southwestern Arkansas, supplied an important quantity of iron to the waters tributary to the Tertiary sea. Moreover, waters containing iron derived from the decay of rocks far in the interior of the

continent doubtless reached the coast, just as they do at present. These waters, draining into lagoons and swamps, were subjected to active oxidizing influences which eventually caused the precipitation of the soluble salts of iron contained in them.

THE FORMS IN WHICH IRON IS DEPOSITED AT ORDINARY TEMPERATURES.

General statement.—The chemical or mineralogical forms in which the iron was precipitated in the bottoms of the Tertiary lagoons or bogs doubtless varied considerably, and depended on the local conditions of the water and air, whether of an oxidixing or of a reducing nature, and on the associated materials, either in solution or as sediments on the bottoms of the basins in which deposition took place. Iron at ordinary temperatures, such as doubtless prevailed during the deposition of the Tertiary ores, is usually laid down in one or more of four forms, namely: the hydrous sesquioxide, the carbonate, the sulphide, and the silicate of iron and potash known as glauconite. All these forms of iron were probably deposited at different points in the Tertiary strata, but, as will be shown below, the Arkansas ores were probably derived mostly from the first two.

Deposition as oxide and carbonate.—The sesquioxide of iron is deposited when the conditions are of a strongly oxidizing nature, and in special cases under still other conditions. The carbonate is precipitated when the iron-bearing solutions are protected from active oxidizing influences by the presence of a reducing agent, such as decaying animal or vegetable matter, or when they are protected from the action of the air. In either case, however, the protection has to be very complete, as is shown by the fact that even in bogs, which abound in organic matter, the iron is actually precipitated on the vegetation as sesquioxide. At the bottoms of the bogs, however, where the protection is greater than at the surface, the iron often occurs as carbonate. Iron is also frequently deposited as carbonate when the waters containing it in solution meet a precipitant like carbonate of lime, or some other substance capable of extracting the iron from solution and holding it in the carbonate form.

Prof. N. S. Shaler* shows how iron is removed in solution from ferruginous rocks and carried down into underlying limestones, where it is deposited by replacement as carbonate, subsequently altered by oxidation and hydration and thus converted to limonite.

Deposition as sulphide.—The sulphide of iron is precipitated when solutions containing iron are brought into contact with volatile or soluble sulphuretted compounds, derived from the decay of organic matter or from other sources. It is also precipitated when ferruginous waters containing sulphate of iron in solution come in contact with a reducing agent.

The sulphide is a common mineral throughout the Tertiary strata, but, as will be shown later, it probably had less to do with the formation of the Arkansas iron deposits than had the oxide and carbonate; though in Texas, as more fully explained farther on, it appears to have played a part in the formation of certain brown hematite deposits.

Deposition as silicate (glauconite).—Glauconite is essentially a hydrous silicate of iron and potash, containing variable amounts of alumina, magnesia and other ingredients. It occurs in spherical or globular grains which are supposed by some to represent fossil casts, and to have been produced by the combination of iron and potash with the silica from minute sponges which grew in the cavities in which glauconite was subsequently formed.

Glauconite was deposited in considerable quantities in the Tertiary strata, as is shown by the frequent occurrence of large beds of that material, but it probably did not have much to do with the formation of the present Tertiary ores. Glauconite itself contains too much silica and too little iron to be classed as an iron ore; and when it decays *in situ*, a process that takes place slowly and usually with the assistance of acids derived from the decomposition of associated iron pyrites or iron carbonate, it eventually forms a

*Kentucky Geological Survey, Report of Progress, Vol. III., New Series, by N. S. Shaler, 1877, p. 164.

brown mass composed largely of sesquioxide of iron* and silica, which cannot be classed as an iron ore for the same reason that the unaltered glauconite cannot be classed as an ore. When a bed of decayed glauconite, however, is subjected to atmospheric agencies, the sesquioxide of iron in it may be taken into solution, carried off by surface waters and finally be deposited in some form of iron different from glauconite, and thus be the source of a future bed of iron ore. For these reasons, though glauconite alone probably rarely forms iron ore, at least in the Tertiary strata, by its decay *in situ*, this same decay may afford a supply of iron for ore deposits elsewhere. Hence, as stated on page 126, the glauconites of the Upper Cretaceous of Texas may have in part afforded a supply of iron for the Tertiary deposits, while the Tertiary glauconites have probably had but little to do with the formation of Tertiary ores, though they may become a source of iron for future ore deposits.

In cases, however, where a bed of decaying glauconite contains considerable quantities of iron pyrites and carbonate of iron, as is sometimes the case, these minerals become oxidized and are eventually converted to the hydrous sesquioxide (limonite). In such cases the glauconite, becoming decomposed at the same time, may supply a certain amount of hydrous sesquioxide to that derived from the pyrite and carbonate, and thus be partly instrumental in the formation of iron ore deposits by its decay *in situ*. Such an occurrence may have assisted in the formation of certain iron ores of Eastern Texas, to be described later on in this chapter.

THE MODE OF DEPOSITION OF THE IRON IN THE TERTIARY STRATA.

Condition of the iron originally deposited.—The lagoons or bogs, in which the Tertiary ores were deposited, were doubtless the repositories of large quantities of siliceous and argillaceous sediments brought down by the streams from the land, and mixed in the lagoons with more or less vegetable and

*When glauconite decays, the original protoxide of iron in the silicate (glauconite) is converted to the hydrous sesquioxide.

animal matter. The chemical precipitation of the iron would naturally go on simultaneously with the mechanical deposition of the sediments, and the resulting deposits at the lagoon bottoms would be clays or sands more or less impregnated with organic matter and iron. It seems probable, therefore, that the ore deposits, as now found, are not in all cases the result of a direct deposition of iron in beds of the present size, but that they have often been formed by the segregation, through a process of solution and redeposition, of the iron originally scattered through the mechanical sediments. What makes this still more probable is the nodular or concretionary character of much of the ore, a form in which it would not be likely to be deposited by direct precipitation in open waters, and also the fact that small ore-bearing areas of only a few square yards are often separated by barren areas, a feature that points strongly to the influence of a segregating action.

Segregation of the iron.—The segregation probably often went on in the loose mud and sand at the bottoms of the lagoons or bogs, though it may also have taken place in part while the coastal region was being elevated into a land area. The process that probably went on was the solution of the originally precipitated oxide and carbonate of iron, by the action of acids derived from organic matter, and the transportation of the ferruginous solutions by the circulating waters, until they reached a place where they met conditions which caused the precipitation of the iron, as already explained on pages 127–129. Where the ores were segregated at the bottoms of lagoons or bogs, strata of sand and clay would subsequently be deposited on them, and thus they would occupy the interbedded position in which they now occur. In the cases where segregation took place during the elevation of the lagoons or bogs into land areas, the waters carrying the ferruginous solutions would naturally follow the easiest passages. As the bedding planes were doubtless in many cases the most open courses for the waters, the ores would be deposited in these positions.

Forms in which the iron was deposited and segregated.—It is probable that the iron which was the source of the Arkansas ores was originally deposited with the mechanical sediments, before segregation, in the form of either oxide or carbonate. It is not probable that it was in the form of sulphide, for if it were, where segregation had not taken place, some signs of the original sulphide condition of the ore should still be seen, and such is not the case. Where segregation did take place, the iron was probably not in the form of sulphide, for in that form it would have been insoluble in the weak organic acids which were instrumental in causing segregation. The sulphide of iron could be oxidized and the product of its decomposition segregated, but the conditions which existed during most of the segregation in question were probably of a reducing, rather than an oxidizing nature. The silicate (glauconite) could not have been the original form of the iron ore, whether segregation had taken place or not, for somewhat the same reasons as those already given for the sulphide.

As the four forms in which iron is usually precipitated at ordinary temperature are the oxide, carbonate, sulphide and silicate (glauconite), and as it has been shown that the last two were probably not the original forms of the ore, it becomes necessary to conclude that the iron was originally deposited with the mechanical sediments in the forms of oxide or carbonate, or both. The form in which the iron was redeposited after segregation was probably as carbonate, since there is every reason to believe that the present limonite (nodular) ores of the Tertiary area of southern Arkansas have been largely, if not entirely, derived from the oxidation of this material.

The carbonate of iron is of common occurrence throughout the Tertiary strata, though it is usually seen only in protected places, such as in well-borings, in some creek bluffs, and in other places in which it has not been exposed to atmospheric agencies for a sufficiently long time to undergo oxidation; while, where it has been so exposed, it has been oxidized, and partly or completely converted to a more or less hydrous

sesquioxide (limonite.) The strongest evidence of this derivation of the nodular limonite ores is, that in many places they can be seen in the actual process of transition from carbonate of iron to sesquioxide; and it is not an uncommon occurrence to find masses of the as yet unoxidized carbonate, in its impure form known as clay-ironstone, composing the kernels of nodules of limonite, the kernels and the oxidized crusts blending gradually into each other. When the carbonate has been completely oxidized, the ore is either composed of concentric layers separated by cavities, or it is massive on the outside and hollow inside, forming geodes, commonly known as "iron pots." The clay or ochre, already mentioned as often occurring in the geodes, doubtless represents the residual product left after the oxidation of the impure carbonate.*

THE ORIGIN OF LIMONITE GEODES.

The formation of the hollow spaces in the limonite geodes described above, is doubtless due to the gradual shrinkage in the transition from carbonate to sesquioxide of iron. The process which goes on is the evolution of carbonic acid from the carbonate, and the oxidation of the protoxide of iron to the sesquioxide, accompanied at the same time by the hydration of the latter. Dr. T. Sterry Hunt shows† that this shrinkage causes a diminution of volume equal to 19.5 per cent of the original mass of the carbonate. The transition progresses from without inwards, sometimes forming layer after layer of oxide, separated by spaces resulting from contraction; while in other cases the whole shrinkage is represented by one central cavity, and the crust is solid ore. Hence, sometimes the concentric nodules occur, and sometimes the geodes or "iron pots."

Additional evidence of the derivation of the limonite ores from the carbonate, is had in the fact that the masses of ore are often composed of aggregations of angular geodes separated

*This mode of derivation of limonite is not confined to the Tertiary ores; it is described by various writers in the cases of iron ores in other regions and in different geologic horizons.

†Mineral Physiology and Physiography, 1889, p. 262.

LIMONITE GEODES, NEVADA COUNTY.

by cracks, the outside angles of the geodes being so arranged that, if they were brought together, they would form one solid mass of geodes. In some of the unaltered carbonate of iron, or clay-ironstone masses, there are numerous shrinkage cracks, and it seems probable that the shape of the angular geodes has been regulated by the directions of such cracks, which caused the original carbonate to be more or less divided into separate parts, each part afterward forming a separate limonite geode. This subject is rendered clearer by referring to plate IV, which represents a mass of angular geodes separated by open cracks. It will be observed that the sides of the adjoining geodes, if brought close together, would fit each other and form a solid mass, just as the sides of the individual fragments of a mass of carbonate of iron, fractured in various directions by shrinkage cracks, would fit if brought together.

The formation of limonite by the oxidation *in situ* of carbonate of iron, as just described, has probably been going on in the Tertiary region of Arkansas ever since it was raised to a land area, and, as already stated, it can be seen progressing even at the present time.

FERRUGINOUS SANDSTONES AND CONGLOMERATES.

The above discussion of the origin of the iron ores of southern Arkansas does not include the beds of sandstone and conglomerate found in this region, and already mentioned on pages 110 and 125. These are in some cases Tertiary deposits, as is proved by their being interbedded in Tertiary sands and clays, while in other cases they are Pleistocene deposits indurated by ferruginous solutions. The deposits of Tertiary age may often have obtained their iron in the same way as the iron ores just described. In other cases they appear to be simply local areas of loose sands cemented at various epochs, probably in many cases after the elevation of the region into a land area, by iron deposited from percolating ferruginous solutions. This supposition is rendered still more probable by the the fact that the sandstones are of very uncertain thickness and extent, thinning out and thickening rapidly, and often abruptly

passing, laterally, along the strike of the stratum containing them, into loose sands. The iron in the cementing solutions was probably derived from the strata of the region.

In Texas, bodies of a conglomerate or a breccia, composed of fragments broken from the deposits of ore in the hills and cemented together along the creeks, occur in considerable quantities; but, with few exceptions, no considerable beds of such materials occur in Arkansas, the conglomerates in this state being mostly composed of siliceous pebbles cemented in a sandy matrix.

THE BROWN LAMINATED ORES OF TEXAS.

As already stated (pages 105–106), the Tertiary iron ores of Texas occur in two distinct positions in the Eocene series, while those of Arkansas occur mostly in one. The ores occupying the lower position in Texas doubtless had an origin similar to that already described for the Arkansas ores; but the ores occupying the upper position seem to have had a somewhat different mode of derivation, though the main features of their deposition were probably much the same.

The ore in this upper position in Texas is a brown hematite of a rich chestnut color, and often resinous in lustre. The most characteristic feature of the ore is its laminated structure, the laminae varying from a sixteenth to a quarter of an inch in thickness. The laminae are separated by narrow spaces, often containing a gray clay, and are frequently coated with a black gloss. Sometimes the laminated ore blends into a more massive variety. The ore occurs in horizontal beds from one to over three feet in thickness, sometimes continuous over many acres, and elsewhere in isolated patches. It is composed of masses which are flat or slightly concave on top, and bulging or mammillary below. It overlies a bed of glauconite, which varies from thirty to forty feet in thickness, and which is underlain in turn by a series of sands and clays. Sometimes, though not always, the ore is separated from the glauconite by a thin layer of clay. The ore sometimes crops out on the immediate summits of flat-topped hills, but is more often

covered by from one to twenty feet or more of clayey sand, which represents the remains of the overlying strata. The glauconite bed contains considerable quantities of iron pyrites and numerous Claiborne fossils.*

Sometimes thin seams of iron ore occur in the glauconite below the main ore bed, but they are usually small. Between the main ore bed and the overlying clayey sand, there is a layer of hard, dark brown sandstone, varying from less than one inch to six inches in thickness, and averaging probably one and a half inches. It adheres closely to the ore when the latter is broken. The ore crops out on the brinks of the hills, forming protruding rims or crowns, and often covering the slopes with large masses that have broken from the main bed.

The laminated ores are especially well developed in Cherokee county in eastern Texas. They appear to have been derived largely from iron pyrites,† assisted possibly in some cases by carbonate of iron and glauconite. As already stated, the ore directly overlies a large glauconite bed, and in this, and immediately above it, iron pyrites is of common occurrence. In some few places, where natural conditions have protected the bed from atmospheric influences, it is found that the pyrite is especially abundant at the top of the glauconite bed and immediately below the overlying clayey sand. Here it occupies the same position as the laminated ore elsewhere, and is frequently associated with sands and clays which often contain lignite.

The following section at the McBee school-house, near Alto, Cherokee county, Texas, shows a case of the original condition of the iron pyrites:

*See The Eocene Mollusca of the State of Texas, by Angelo Heilprin, Proc. Acad. Nat. Sci. Phila., part III., Oct.-Dec., 1890, pp. 393-406

†The brown hematites of Marion and neighboring counties in northeastern Texas appear to have been derived from the carbonate of iron, as already explained in the case of the Arkansas ores.

Section at McBee School-house, Cherokee county, Texas.

1.	White clayey sand	10-30 feet
2.	Ferruginous sandy clay becoming indurated at base	1 foot
3.	White sandstone with a cement of profusely disseminated iron pyrites	1-3 inches
4.	White sand with lenticular masses of lignite (1 to 4 inches in thickness) and many disseminated particles of iron pyrites, passing below into a plastic greenish brown clay	3 feet
5.	Dark green glauconite at the bottom of the section	......

This section appears to represent the original condition of the strata before the formation of the laminated ore. That ore usually occurs above the glauconite represented in number 5 of the section, but here the same position, that is, above the glauconite and below the clayey sand, is occupied by about four feet of sand and clay strata (members 2, 3 and 4 of the section) highly charged with iron pyrites and other iron-bearing materials. Iron pyrites, by its oxidation, forms sulphuric acid and sulphate of iron, the latter sooner or later becoming still further oxidized and going into a hydrous sesquioxide of iron. It seems probable that the combined action of the sulphuric acid and sulphate of iron, percolating down from the pyritiferous sands into the clay, causes an interchange of constituents, and that the clay is to a greater or less extent converted into iron ore. This would account for the considerable percentage of alumina usually found in the ore, and also for the laminated structure of the ore, a structure often seen in the unaltered clay. Such a supposition would also account for the fact, that the base of the ore bed often seems to blend into the layer of clay which has already been mentioned (page 134) as sometimes occurring between the ore bed and the underlying glauconite. The thin layer of sandstone, which has already been mentioned as capping the laminated ore, is probably due to the induration of the sandy stratum immediately overlying the clay, by sesquioxide of iron derived from the oxidation of the pyrite. The sandstone frequently contains masses of lignite completely converted to iron ore, and these probably represent the alteration products of the lignite originally associated with the pyrite.

The shape of the ore bed is strong evidence of the formation of the ore by the process just described: the upper surface of

the bed, as a whole, is usually flat, but its base is very uneven, and shows a series of bulging and receding mammillary forms. The ore is often in separate masses, but they are closely assembled together in a continuous or almost continuous stratum. The upper surfaces of the individual ore masses are often slightly concave, while the lower surfaces are convex, apparently pointing to a derivation by the downward percolation of the ferruginous solutions as already described.

The glauconite itself may in some cases have assisted in the formation of the laminated ore, but its influence has probably been small. Glauconite, as explained on page 129, is doubtless an important source of iron in surface waters, and the ferruginous solutions derived from it may often be precipitated elsewhere, and be accumulated in considerable beds of ore; but the case in question is the formation of brown hematite *in situ*, and in such a process glauconite does not seem, at least in the Tertiary area of Texas and Arkansas, to have been so important a factor as other forms of iron; moreover, in the Texas region a thin layer of clay often intervenes between the ore and the glauconite, thus lessening the probability of the latter having had a part in the formation of the ore deposits.

Beside the pyrite at the top of the glauconite bed, the same mineral is often found in greater or less quantities lower down in the formation, and where it has been oxidized it gives rise to masses and layers of limonite. Carbonate of iron in the form of layers or nodules, or as a finely disseminated material, is also a common constituent of the glauconite formation, and by its oxidation it also gives rise to the hydrous sesquioxide. The ferruginous solutions derived from the pyrite or carbonate often percolate through the glauconite bed, and deposit thin layers of limonite in joint cracks and along lines of bedding, giving the impression that the ore has been derived from the oxidation of the glauconite. In some cases the glauconite has undoubtedly supplied a part of it, but the fact that the largest quantities of limonite are found in those parts of the glauconite beds which contain most carbonate or sulphide of iron, is strongly suggestive of the greater influence of the last two

as sources of the limonite. The long-continued action of sulphuric acid derived from the oxidation of pyrite, and of carbonic acid derived from carbonate of iron, have, however, had their effect in decomposing the glauconite, and their influence is shown by the fact that, where oxidation has gone on in the pyrite and carbonate, the originally green glauconite is converted to a yellow or rusty, and more or less indurated mass. Sometimes it is hardened to such an extent that it is used for a building stone. A similar alteration of the glauconite takes place even where the sulphide and carbonate are absent, but less rapidly than where they are present. In fact, in the region of the ores associated with glauconite in eastern Texas, the whole formation presents a yellow or brown surface exposure, while at depths of from a few inches to twenty feet or more in the interiors of the hills, the original green color is preserved.

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LIST OF THE PUBLICATIONS OF THE GEOLOGICAL SURVEY OF ARKANSAS.

The following list includes all of the official publications known to have been made by the several Geological Surveys carried on by the State of Arkansas. The reports, when not out of print, may be had of The Honorable, The Secretary of State, Little Rock, Ark., at the prices mentioned :

(*A.*) *By the Survey under D. D. Owen, State Geologist.*

First Report of a Geological Reconnoissance of the Northern Counties of Arkansas made during the years 1857 and 1858..............Price $3 00

Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas made during the years 1859 and 1860..Price $3 00

(*B.*) *By the Survey under W. F. Roberts, Sr., State Geologist.*

Report by George Haddock ....(Out of print)

(*C.*) *By the Survey under J. C. Branner, State Geologist.*

Annual Report of the Geological Survey of Arkansas for 1887, by J. C. Branner ....Price 0.10

Vol. I for 1888, Report upon the Geology of Western Central Arkansas, with especial Reference to Gold and Silver, by Theo. B. Comstock..Price $1 00

Vol. II for 1888, The Neozoic Geology of Southwestern Arkansas, by R. T. Hill..Price $1 00

Vol. III for 1888, The Geology of the Coal Regions; a Preliminary Report upon a Portion of the Coal Regions of Arkansas, by Arthur Winslow ....Price 0.75

Vol. IV for 1888, Part I, The Geology of Washington County, by Frederic W. Simonds; Part II, a List of the Plants of Arkansas, by J. C. Branner and F. V. Coville.............................Price $1 00

Vol. I for 1889, Clays, Kaolins and Bauxites, by J. C. Branner..(In press)

Vol. II for 1889, The Geology of Crowley's Ridge, by R. E. Call..Price $1 00

Vol. I for 1890, Manganese: Its Uses, Ores and Deposits, by R. A. F. Penrose, Jr ....Price $1 35

Vol. II for 1890, The Igneous Rocks of Arkansas, by J. Francis Williams. $1 35

Vol. III for 1890, Whetstones and the Novaculites of Arkansas, by L. S. Griswold ....Price $1 60

Vol. I for 1891, Mineral and Other Waters.... ....(In press)

Vol. I for 1892, The Iron Deposits of Arkansas, by R. A. F. Penrose, Jr.. .....